









**BULLETIN OF
THE AMERICAN
MALACOLOGICAL
UNION, Inc.**

for 1977

**FORTY THIRD ANNUAL MEETING
Naples, Florida — July 10-15, 1977**

The American
Malacological Union



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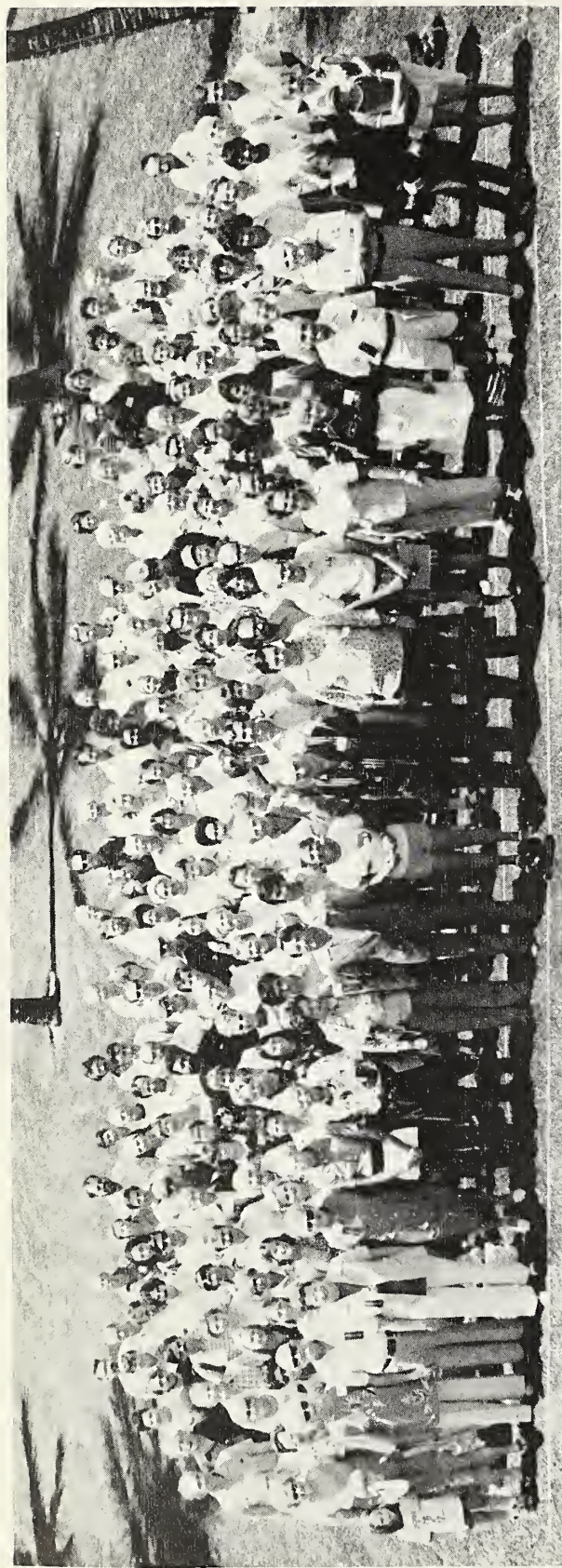
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AMU '77 — Naples, Florida
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AMERICAN MALACOLOGICAL UNION, INC.
Forty-Third Annual Meeting

July 10-15, 1977
Naples, Florida

The Forty-Third Annual Meeting of the American Malacological Union was held July 10-15, 1977, at the beautiful Beach Club Hotel at Naples, Florida, with a setting of private beach sands on the Gulf of Mexico, and blue-green waters and rolling surf to soothe one's spirits. For the more athletically-inclined, tennis courts and the golf course were across the street.

The 247 registrants attended a finely-executed professional session that brought special participants from the British Systematics Association for an excellent Symposium on the Evolution and Adaptive Radiation of Mollusca. Led by delightful Dr. Arthur J. Cain of the Department of Zoology of the University of Liverpool, England, the English representatives joined AMU professionals for discussions on a specialized subject that lasted from 8 a.m. on Tuesday through the first part of Wednesday morning.

Evenings were planned to entertain and provide time to talk about shells and to meet new and old friends. President George Davis' reception in the Promenade Room on Sunday evening gathered early registrants. A slide program of scenes from past AMU meetings provided some fun as members saw themselves some years younger.

The West Indian Fauna Night on Monday was planned as a Mini-Symposium on the Mollusca of the West Indies. Participants provided a good picture of the faunal history and present collecting hints. Good slides of animals and shells delighted the audience.

Shell Club night really was a book auction. A full house of members and visitors bid on out-of-print books and memorabilia of interest to shell collectors. New books donated for the auction and reprints donated were eagerly sought by shellers. Announcements of interest to shellers, travelogues, and a fine historical report of early U.S. malacologists made by Dr. Harry Lee completed the program.

Wednesday dawned bright and sunny, quite perfect for the five field trips planned that day. Most members had found it difficult to choose which field trip to attend. Some couples split up in order to get specimens from at least two trips. The trip into the Everglades to get *Liguus* was certainly the most popular. Despite scratches, bites, and other "slight"

inconveniences, the happy smiles from collectors coming home with the beautiful Florida tree snails spoke of the success of this trip led by Archie Jones and Fran Thorpe. Two fine fossil trips were provided, planned by Dr. Gary Schmelz of the Big Cypress Nature Center of Naples. Buckets of fossils were available to those wishing to haul them home.

Admiral Gordon Selby was in charge of the snorkelers and the scuba divers who went out to get live marine shells. Some of these shells were photographed and studied during the meeting. Others were pickled and destined for museums: Bernie Yokel of the Rookery Bay Conservation Area ran the oyster bed collecting, and Chuck Courtney of the Marco Island Ecology Laboratories led a dredging expedition.

Wednesday night, while Council met, members were treated to a presentation on a preliminary look at the marine fish and invertebrates of the Southern Gulf of Mexico, with Gary Schmelz, director of the Big Cypress Nature Center of Naples, as speaker.

Thursday night the Council of Systematic Malacologists met and other members heard a special program entitled "The Oyster As Architect of the 10,000 Islands Eco-System" presented by Bernie Yokel. Afterwards, everyone ended up at the Texas Party given by Texans at the meeting.

After the final sessions and business meeting on Friday, the sunset seemed especially arranged for the cocktail hour on the lawn before the sumptuous banquet in the Everglades Room. The toasts seemed most appropriate to signal this meeting an outstanding event. The roasts of former presidents and officers by President Davis brought down the house. Remarks from the chairman of the local committee, Jerry Bijur, told of his long struggle to get AMU to meet at his beloved Naples. Dr. Cain's address was lively and thought-provoking. Applause and standing ovations for all those so involved in making this meeting a memorable one attested to the appreciation felt by everyone. Dr. Cain promised to come again if he got an invitation. All of us hoped to visit Naples again someday.

New president Carol Stein announced that the Forty-Fourth Annual Meeting of AMU would be held in July on the Wilmington campus of the University of North Carolina. See you there!

Constance E. Boone

CONTRIBUTED PAPERS PRESENTED AT THE 1977 MEETING

NINETEENTH CENTURY MALACOLOGISTS OF THE AMERICAN SOUTH

Harry G. Lee
709 Lamax Street
Jacksonville, FL 32204

The last century was an epoch of unparalleled activity in descriptive natural history. American malacology was being written by the pioneers and giants of the past. Say, C.B. Adams, Lea, Gould, Binney, Bland, Conrad, Anthony, later Tryon, Dall, and Pilsbry. These men, though not all professionals in the strictest sense, had close ties with the museums and learned societies of our northern cities.

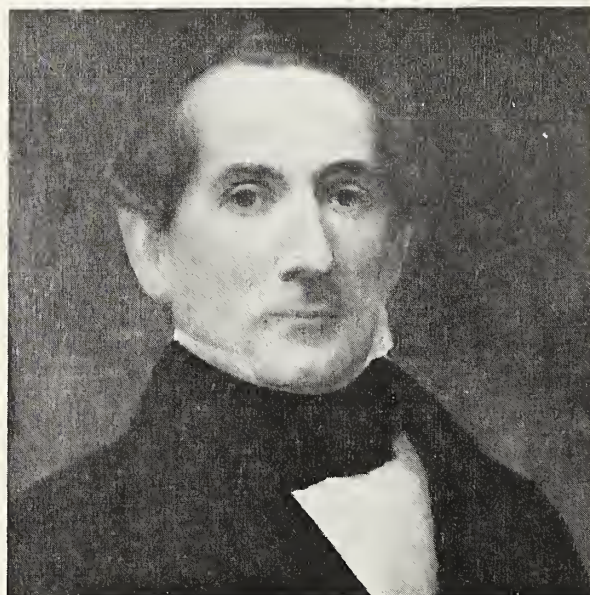
In the South things were different. King Cotton ruled a rural domain, and such institutions were barely embryonic. What it did have was a rich natural history which, except for the Batrams' intrusions, was virtually untapped in 1800. By the end of the century, the vast majority of its mollusks were known, not only from the fruits of Yankee expeditions, but also through the provenance of Southern naturalists—amateurs who lived and worked in a epoch which saw the peak and decline of the Cotton Culture. Generally occupied with more practical pursuits, these men left the job of describing their species and recording their observations to the familiar luminaries of Philadelphia, Washington and Boston.

These Southern naturalists were close to the soil, most were planters or planters' sons but could scarcely qualify as rustics. The following brief profiles attempt to illustrate how their lives interacted with the cultural, political, economic and natural environment of the Old South.

James Hamilton Couper was born in 1794 in Sunbury, Georgia. His father, John, was a Scottish immigrant who had brought to fruit a fine plantation on St. Simons Is. Here at Cannon's Point young Couper learned his agronomy first-hand and took note of his father's friendship with contemporary naturalists like Thomas Jefferson. Couper was sent North and returned at age 20 having graduated first in his class at Yale. He married Carolyn Wyllie in 1827 and the couple took up residence on Hopeton Plantation, a picturesque tract on the right bank of the Altamaha River just above Darien. His innovative and systematic approach to the culture and processing

of cotton, rice, and cane made Hopeton an eminent success. The consequent flow of agriculturalists and other prominent and learned people to Hopeton earned him a certain fame which exceeded Hopeton's productivity as a plantation. Europeans such as Sir Charles Lyell, the geologist, and novelist Frederika Bremer were apparently surprised to encounter a man of such refinement in this quaint setting. Ms. Bremer stated "in urbanity and grace of conversation Mr. Couper reminds me of Ralph Waldo Emerson."

Couper was a naturalist with broad tastes. Although he loved botany and herpetology (the Indigo Snake is named in his honor), mollusks were certainly his favorite group. By 1854 he was the



James H. Couper (1794 - 1866)

"leading conchologist of the South" according to historian George White. Couper's shell collecting was probably limited to the low country of Georgia, but by 1836 he had provided the Philadelphian Isaac Lea with the holotype of *Canthyrina spinosa* (Lea, 1836), that "most extraordinary species of the genus (*Unio*).". The type locality of *Elliptio hopetenensis* (Lea, 1838) was Hopeton's rice

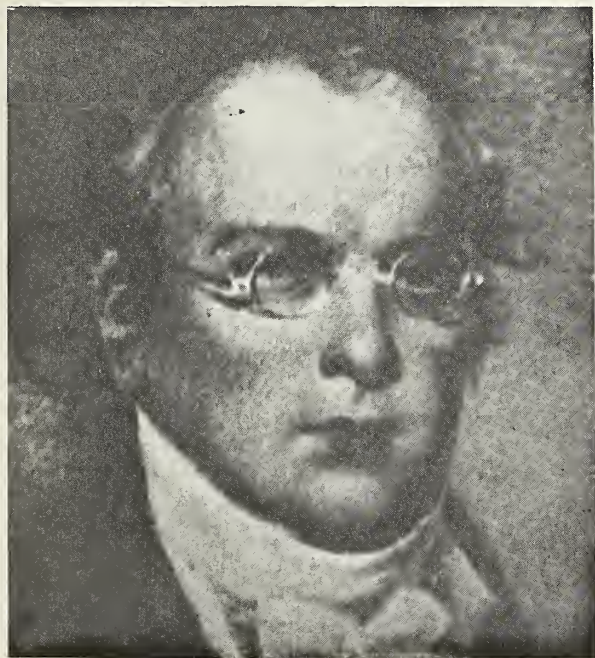
paddies, and no doubt *Triodopsis hopetonensis* (Shuttleworth, 1852) occurred nearby. *Anodonta couperiana* (Lea 1840) and *Elliptio dariensis* (Lea, 1842) are likewise the products of Couper's collecting. He described little *Littoridinops tenuipes* himself in 1844.

In 1857 Couper entered semi-retirement and retreated with Carolyn to a home of his own design he called "Altama". Shortly after the War, which claimed the lives of his two eldest sons, Couper died in quiet seclusion. He now reposes at Christ Church cemetery on St. Simons. The Couper collections went to the U.S.N.M. and in 1861 to the College of Charleston, South Carolina.

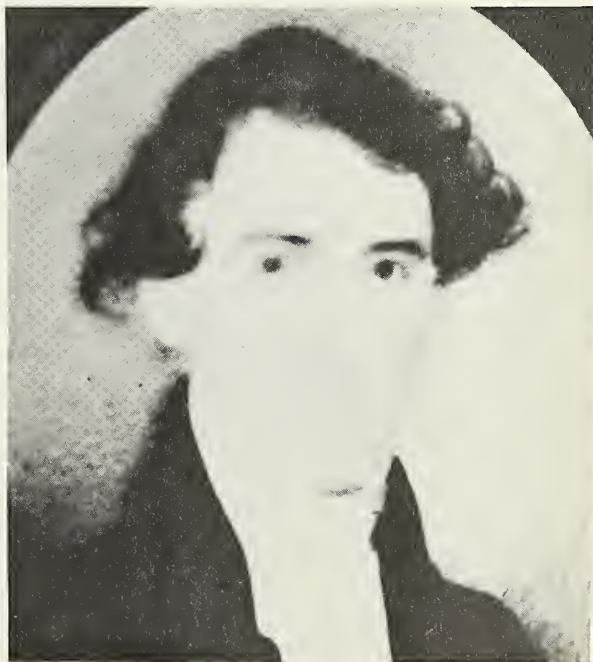
Probably the first important conchologist of the South, Stephen Elliott I, was born in Beaufort, South Carolina in 1771. Like Couper he graduated from Yale as a Phi Beta Kappa at age 20. After tending to plantation business for several years, he emerged in 1812 to become one of the leading public figures in Charleston. Despite his intensive activities in politics and banking he helped found the Literary and Philosophical Society of South Carolina (the Charleston Museum forerunner) and the Medical University of South Carolina where he was First Professor of Botany and Natural History. Although best known as a botanist (the Slash Pine and Paurotis Palm are named in his honor), Elliott was an avid conchologist, and his collections produced at least ten new species, which were

described by his friend Thomas Say. These include *Cerithium muscarum* (Say, 1832), *Siphonaria alternata* (Say, 1826), *Nassarius albus* (Say, 1826), and *Melongena bicolor* (Say, 1826). The Charleston Museum is said to have received his collections.

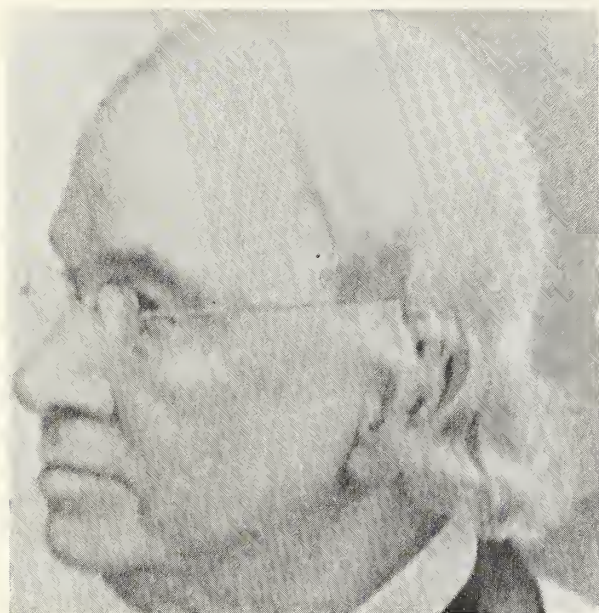
When Elliott died in 1830, his eldest son and namesake was 23 years old. Stephen Elliott II was trained in law but later was called to the ministry. In 1841 he was consecrated First Bishop of Georgia at Christ Church, Savannah (designed by Couper three years earlier). Bishop Elliott became renowned as a educator and naturalist as well as a man of uncommon compassion and piety. Frederika Bremer called him "one of the most beautiful examples of that old cavalier race which gives tone and stamp to the nobler life the Southern States." Cast from his father's mold, the bishop took ample time while traveling his extensive diocese to carefully collect mollusks. His principal malacological correspondent, Isaac Lea, thanked him: "...malacological science is indebted to you... (who) brought not only a vast number of new species to light, but... carefully collected them with the soft parts, so that I am able to give the chief points of their anatomic structure." At least 74 species were described from the Bishop's collections. These include *Pleurobema pyriforme* (Lea, 1857), *Medionidus penicillatus* (Lea, 1857), and *Ventridens elliotti* (Redfield, 1856). The bishop



Stephen Elliott I (1771 - 1830)



Bishop Stephen Elliott (1806 - 1866)



Reverend George White (1802-1887)

was a founder and Chancellor of the University of the South, where his field notes and that portion of his collection not exported north now repose.

Bishop Elliott was a member of the Royal Society of Conchologists and had international ties. In 1857 he and his son visited Cuba where Stephen III discovered a novel species of land snail. The Elliotts' host, Felipe Poey, rewarded the lad by describing *Callania elliotti* the next year.

The bishop's death in 1866 wasn't the final chapter in the family's involvement in conchology. Nearly 50 years later William Mazýck honored Elliott I by describing *Epitonium elliotti* Mazýck, 1913. Interestingly, modern workers believe this species to be synonymous with *E. multistriatum* (Say, 1826), which was described from a specimen provided by the same Elliott almost a century earlier. Thus the history of the Elliott dynasty came about full circuit and we have an instance, perhaps unique, in which three generations of an American family have had mollusks described in their honor.

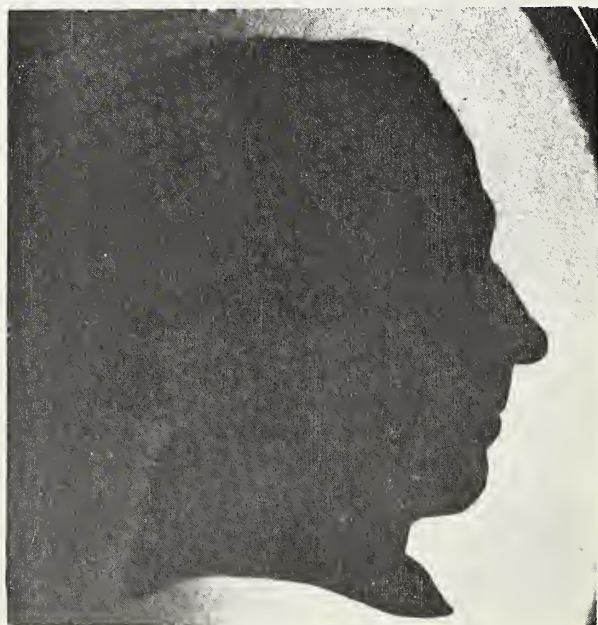
South Carolina produced another important Episcopal clergyman, a contemporary and associate of Bishop Elliott. George White was born in 1802 and ordained a priest in 1836. While rector in several parishes of Alabama, Georgia and Tennessee during his 85 years, his most valid claim to remembrance was his contribution to scholarly history. His work *Historical Collections of Georgia* published in 1854 (and dedicated to J.H. Couper) is today a classic. White was a prodigious collector

of aquatic mollusks and provided Isaac Lea and others with specimens, including the holotypes of *Goniobasis viennaensis* Lea, 1862, *G. whitei* Lea, 1862, *Physa whitei* Lea, 1864 and *Unio whiteanus* Lea, 1852.

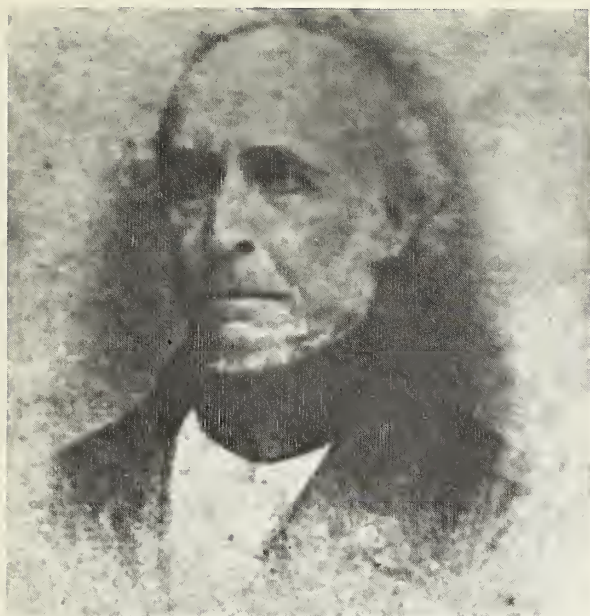
No account of Southern naturalists could overlook the family LeConte. Near the turn of the century John Eatton LeConte began acquainting his sons Louis and J.E. II with the family plantation at Woodmanston, Liberty Co., Georgia. By 1810 Louis had graduated from Columbia, left medicine and become the first LeConte to operate the plantation year-round.

Two years later he married Ann Quarterman of the nearby Puritan settlement of Midway. Woodmanston flourished under his direction and the hydraulics of his rice field irrigation system are a marvel to modern day agriculturalists. He was one of the first to cultivate the Camellia in North America, and he helped develop the LeConte Pear at Woodmanston. One of his favorite haunts was the Altamaha River Ferry some 15 miles south on the Old Barrington Road. In that area he found the holotypes of *Alasmidonta arcua* (Lea, 1836), *Lampsilis dolabraeformis* (Lea, 1838), and *Villosa splendida* (Lea, 1838).

These and other specimens actually reached Philadelphia through Louis' brother, Major John Eatton LeConte II, who left Woodmanston to serve with the Army Corps of Engineers in about 1820. Proclaimed by some as the leading naturalist in the



Louis LeConte (1782 - 1838)



Major John E. LeConte (1784-1860)

South, he was a renaissance biologist describing mammals, birds, turtles, frogs, insects and plants during his peregrinations in the Southeast. His shells included many Say and Lea holotypes such as *Anodonta gibbosa* Say, 1824, *Pomacea paludosa* (Say, 1824) and *Fusconaia succissa* (Lea, 1852).

Louis and the Major had sons who maintained the LeConte tradition. These three were trained in medicine at Louis' alma mater and concluded their careers amidst academic accolades of the highest order.

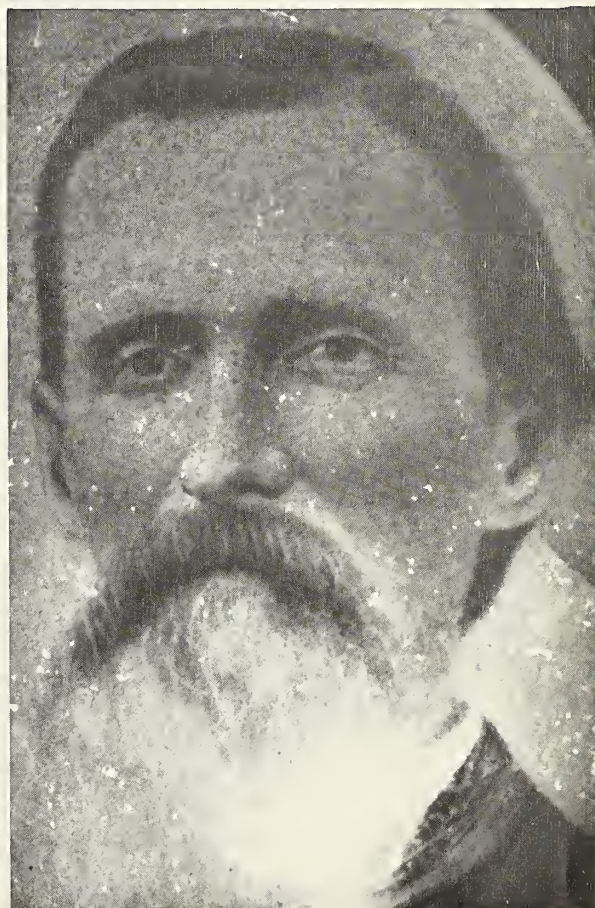
Louis LeConte's son Joseph had no sooner met his mentor Louis Agassiz when he was confined with a collection of 1,000 American naiades for a week with instructions to "pair these valves and classify into species, names no matter." The lad acquitted himself well as Agassiz commended him afterwards for correctly revising the system of Isaac Lea. Later Joseph and brother John abandoned medicine and had scarcely begun their academic careers when the war struck. Postwar conditions under carpetbagger rule were intolerable, and the brothers joined the new University of California as science professors. The rest is history ... John's ascent to the Presidency of the University in 1875, Joseph's classic work on the geology of the West, and his association with John Muir which culminated with the founding of the Sierra Club in 1892. After Joseph's death in 1901 R.E.C. Stearns honored his memory by describing *Pyramidula lecontei*

Stearns, 1902.

Major LeConte's son, John Lawrence, was a friend, fellow traveller, and classmate of his cousins. He too left the South and later became an authority on the Coleoptera. He didn't ignore mollusks bringing much new fossil and recent material back from his western expeditions including *Rangia lecontei* (Conrad, 1853). He served as president of the A.A.A.S. in 1874—a post his cousin Joe assumed 17 years later.

The last born and probably the most prodigious collector of the group was James Postell. Like Louis LeConte he was of Huguenot descent and moved to Georgia about the time of his marriage. Through his union with Ann Armstrong Cater, Kelvin grove plantation on St. Simons Island became his responsibility.

James was self-educated and only 28 when the war struck. He returned in 1865 to find 10 families of freed slaves occupying Kelvin grove. He eventually regained control of the plantation, but it was clear that agriculture could no longer sustain the



James Postell (1833 - 1893)

family. He worked as a civil engineer in nearby Brunswick, store manager for Dodge's Lumber Mill on St. Simons, experimented with chick-raising and finally erected the first big hotel on the island. Postell's industry was also reflected in his shell collections, of which there were several. One comprised 6,000 varieties and was dispatched to Roanoke College and another of "5,000 species and 40,000 specimens" was donated to the Young Men's Library Association in Atlanta. Postell was fond of seashells but also collected terrestrial and aquatic mollusks discovering *Mesodon thyroidus sanctisimonis* (Pilsbry, 1901), *Polygyra postelliana* Bland, 1859, and *Goniobasis catenaria postellii* Lea, 1858. He died in his 60th year and was buried at Christ Church a few yards from kindred spirit, James H. Couper.

Today Kelvin Grove is a mixture of subdivisions and part of an airport. St. Simons has no people of his surname, but it has Postell Drive and Postell Creek as mementoes of its eminent conchologist.

This survey certainly fails in its lack of thoroughness. Names like Hallenbeck, Ravenel, Troost, Spillman, Sloat, Boykin, Downie, Showalter, Andrews, and Law at least deserve mention and their omission is more the result of the writer's lack of resourcefulness than any other factor. It seems, however, that their lives would probably further exemplify the character of Couper, White, Postell, the Elliots and LeContes as people who were in part the product of their locale and times but who, on the other hand, driven by unusual curiosity, improved the human condition through better knowledge of their natural surroundings. With the more superficial and tangible trappings of the Old South gone with the wind, these spirits tend to recall the unencumbered ideal ... The Southern Gentleman.

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THE NAIAD MOLLUSKS OF THE MISSISSIPPI RIVER
IN THE VICINITY OF PRAIRIE DU CHIEN, WISCONSINMarian E. Havlik
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and

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There currently is an increase in efforts to determine which species of freshwater mollusks are declining in overall range or are decreasing in population density within their range. Such efforts are frequently frustrated by the inadequacy of data. Investigators are fortunate indeed if they can locate a truly comprehensive list of mollusk species for a specific site recorded more than 50 years ago. Quantitative records indicating how many specimens of the various species were found and how intensively the site was collected are almost nonexistent. Some exceptions to these generalizations do, however, exist.

One such fortuitous site on the Mississippi River, represented by several accounts over the past three quarters of a century, is the area near McGregor, Iowa and Prairie du Chien, Wisconsin. These towns lie on opposite sides of the river and flank a large bed (or beds) of naiad mollusks. This source of commercial shell has been harvested intermittently from the 1890's to the present.

Naiad records from Prairie du Chien date from 1823, when D.W. Barnes described *Unio giganteus* and *Unio ventricosus* from this site.

The earliest known molluscan faunal list for Prairie du Chien is that of Baker (1905). In 1904 he purchased 1½ bushels of naiades from a commercial sheller and used this material as the basis of his report. He identified 34 species of bivalves but noted, "It is probable that a more extended study, covering several years, would bring to light many additional species."

Shimek (1921) collected over a period of several years and produced a list of 43 species for the Prairie du Chien-McGregor area. This is the greatest number of species ever recorded for this site and includes 5 species never subsequently found there. Shimek's records for *Alasmidonta marginata* Say, 1818, *Lasmigona costata* (Rafin-

esque, 1820), *Quadrula fragosa* (Conrad, 1835), *Pleurobema rubrum* (Rafinesque, 1820) and *Lepetodea leptodon* (Rafinesque, 1820) remain the only records of these species for Prairie du Chien. *Quadrula fragosa*, *Pleurobema rubrum* and *Lepetodea leptodon* have been frequently confused with closely related species but Shimek lists the superficially similar species in each instance, thus supporting the accuracy of his identifications.

Baker included 27 naiad species and subspecies that he collected at Prairie du Chien in 1920-22 in his 1928 monograph on the freshwater mollusks of Wisconsin. His list duplicates and hence supports the corresponding records of Shimek (1921) and Baker's own list of 1905.

During the summers of 1930 and 1931 Dr. Max M. Ellis and his staff surveyed selected sites on the Mississippi River above the mouth of the Missouri. The Prairie du Chien site was one of those collected. Following the death of Dr. Ellis, Dr. and Mrs. Henry van der Schalie obtained the Mississippi naiad collections of Ellis and published the results in 1950. They listed 31 naiad species obtained by Ellis from Prairie du Chien, all but one of which duplicated (and hence validated) the records of Shimek (1921). The single species added to the list was *Simpsonaias ambigua* (Say, 1825). This diminutive naiad has a salamander, the Mudpuppy, *Necturus m. maculosus* Rafinesque, 1819, as its glochidial host. It seems erratically disturbed within the range of the host and, perhaps because of its habitat beneath large flat rocks, is only occasionally collected. This record brings the Prairie du Chien naiad list to 44 species. At the present time, the Prairie du Chien site has the greatest diversity of naiad mollusks known from any site on the Mississippi River.

During the period from the Ellis collections of 1930-31 to 1976 the Prairie du Chien site has been

subject to the rigors of World War II industrial pollution, postwar agricultural runoffs rich in fertilizers and pesticides, channel maintenance dredging, and recent shell harvesting for the cultured pearl industry in Japan.

In July of 1976 the East Channel of the Mississippi River (River Mile 635.3 to 636.3) at Prairie du Chien had 104,000 cubic yards of substrate removed by a dredging operation. This area has been a productive site for commercial shellers and they had taken specimens of *Lampsilis higginsii* (Lea, 1857), a species now on the federal list of ENDANGERED AND THREATENED WILDLIFE and PLANTS. Voucher specimens are in the collection of the senior author.

The disposal area for the dredge spoils was examined following the two weeks of dredging. Thousands of fresh naiad shells, many with the soft parts dried or decomposing within them, were found in the dredged material. Some of the salable species were gathered by those living nearby and sold to commercial buyers. The senior author, along with friends and relatives, made repeated trips to the site in an effort to collect at least some specimens of every species present. Five field trips yielded over 1,600 specimens, most of which were unmatched valves. These were sent to The Ohio State University Museum of Zoology where all identifications were checked by the junior author and samples of each of the 33 species found were catalogued into the bivalve mollusk collection. Three species, *Plethobasus cyphus* (Rafinesque, 1820), *Elliptio c. crassidens* (Lamarck, 1819) and *Actinonaias ligamentina carinata* (Barnes, 1823), were represented by subfossil specimens only. At least some specimens of all the remaining 30 species were fresh or nearly so. At least 14 specimens of *L. higginsii* were found, indicating the presence of what may be the largest (or perhaps the most dense) aggregation of this species known.

A comparison of the collections made by Baker in 1904; by Shimek prior to 1921; by Baker in 1920-22; by Ellis in 1930-31 and by Havlik in 1976 (See Table 1) reveals faunal changes over at least half a century as follows:

1. The fauna is reduced from 44 to 30 species and subspecies, a loss of 14 species (32 per cent). However, living specimens of both *Actinonaias ligamentina carinata* and *Lampsilis radiata luteola* were taken at Prairie du Chien during the late summer of 1977. This brings the current fauna to 32 species and subspecies indicating a loss of only

12 species (27 per cent) in the 55 years since the time of Shimek (See Table 2).

2. At least four species of the 12 missing today typically inhabit medium-to-small rivers and were probably never common at the Prairie du Chien site. These include *Anodonta grandis grandis*, *Alasmodonta marginata*, *Simpsonaias ambigua*, and *Lasmigona costata*.

3. Of the remaining 8 species, at least five appear to be reduced or extirpated throughout much of their range (Stansbery, 1971: 12-14). These are *Cumberlandia monodonta*, *Quadrula fragosa*, *Pleurobema rubrum*, *Leptodea leptodon*, and *Potamilus capax*.

A few living specimens of *C. monodonta* (OSUM 39943) have been taken and shells of *P. capax* have been reported from elsewhere in the Mississippi River within the past year. The others have not been seen at Prairie du Chien for over 50 years and may be extirpated. These five species appear to be hypersensitive to some decimating factor(s) throughout their range.

4. Of the three remaining species, *P. cyphus*, and *E. c. crassidens* are represented only by subfossil shells. *Cyclonaias tuberculata* was not found in any form. Rather extensive recent collections of upper Mississippi naiades deposited at OSUM indicate that *E. c. crassidens* and *C. tuberculata* may now be extirpated from the river while *P. cyphus* is still living at other places in the Mississippi main stem.

Lampsilis teres form fallaciosa comprised nearly half (48 per cent) of the total number of specimens taken in 1930-31 by Ellis. This may reflect Ellis' thoroughness in sampling a relatively firm silt bank. The common names, "Slough Sand Shell" and "Bank Climber", attest to the habitat of this form.

5. The collection of eight living specimens of *L. higginsii* (OSUM 40044) on 2 July 1977 from the area immediately below the site dredged in 1976 indicates: a) that this species still survives in the Mississippi River at Prairie du Chien and b) that this site is a prime candidate for designation as critical habitat for this species.

6. The Mississippi River naiad fauna may well be less damaged than that of any other large river in North America today. Data from the Tennessee River at Mussel (or Muscle) Shoals (Stansbery, 1964) reveal a loss of over 52 per cent of the original naiad fauna, and our estimate for the Ohio River at Cincinnati indicates a similar loss. In contrast, the Mississippi River at Prairie du Chien

TABLE 1

NAIAD MOLLUSKS OF THE MISSISSIPPI RIVER
IN THE VICINITY OF PRAIRIE DU CHIEN, WISCONSIN

FAMILY MARGARITIFERIDAE	B ₁	S	B ₂	E	H
1. <i>Cumberlandia monodonta</i> (Say, 1829)	X	X	X		
FAMILY UNIONIDAE					
Subfamily Anodontinae (Rafinesque, 1820) Ortmann, 1910					
2. <i>Anodonta imbecillis</i> Say, 1829		X		10	4
3. <i>Anodonta grandis grandis</i> Say, 1829	X	X	X		
4. <i>Anodonta grandis corpulenta</i> Cooper, 1834	X	X	X	81	1
5. <i>Strophitus undulatus undulatus</i> (Say, 1817)	X	X	X	1	7
6. <i>Alasmodonta marignata</i> Say, 1818		X			
7. <i>Arcidens confragosus</i> (Say, 1829)	X	X	X	3	5
8. <i>Simpsonaias ambigua</i> (Say, 1825)				1	
9. <i>Lasmigona complanata</i> (Barnes, 1823)	X	X			6
10. <i>Lasmigona costata</i> (Rafinesque, 1820)	X	X			
Subfamily Ambleminae (Rafinesque, 1820) Morrison, 1955					
11. <i>Megalonaias nervosa</i> (Rafinesque, 1820)	X	X	X	15	55
12. <i>Tritogonia verrucosa</i> (Rafinesque, 1820)	X	X	X	23	9
13. <i>Quadrula quadrula</i> (Rafinesque, 1820)	X	X	X	1	77
14. <i>Quadrula fragosa</i> (Conrad, 1835)		X			
15. <i>Quadrula metaneura</i> (Rafinesque, 1820)	X	X	X	1	18
16. <i>Quadrula nodulata</i> (Rafinesque, 1820)	X	X	X	8	68
17. <i>Quadrula pustulosa</i> (Lea, 1831)	X	X	X	33	164
18. <i>Amblema plicata plicata</i> (Say, 1817)	X	X		84	183
19. <i>Fusconaia ebena</i> (Lea, 1831)	X	X	X	2	103
20. <i>Fusconaia flava</i> (Rafinesque, 1820)	X	X	X	14	121
21. <i>Cyclonaias tuberculata</i> (Rafinesque, 1820)	X	X	X	1	
22. <i>Plethobasus cyphus</i> (Rafinesque, 1820)	X	X			1*
23. <i>Pleurobema coccineum</i> (Conrad, 1836)	X	X	X		1
24. <i>Pleurobema rubrum</i> (Rafinesque, 1820)		X			
25. <i>Elliptio crassidens crassidens</i> (Lamarck, 1819)	X	X	X		1*
26. <i>Elliptio dilatatus</i> (Rafinesque, 1820)	X	X	X	36	4
Subfamily Lampsilinae (von Ihering, 1901) Ortmann, 1910					
27. <i>Obliquaria reflexa</i> Rafinesque, 1820	X	X	X	34	75
28. <i>Actinonaias ligamentina carinata</i> (Barnes, 1823)	X	X	X	6	8*
29. <i>Plagiola lineolata</i> (Rafinesque, 1820)	X	X	X	4	1
30. <i>Obovaria olivaris</i> (Rafinesque, 1820)	X	X		4	178
31. <i>Truncilla truncata</i> Rafinesque, 1820	X	X	X	23	85
32. <i>Truncilla donaciformis</i> (Lea, 1827)		X		1	76
33. <i>Leptodea leptodon</i> (Rafinesque, 1820)		X			
34. <i>Leptodea fragilis</i> (Rafinesque, 1820)	X	X	X	50	14
35. <i>Potamilus alatus</i> (Say, 1817)	X	X	X	72	12
36. <i>Potamilus laevis</i> (Lea, 1829)		X			9
37. <i>Potamilus capax</i> (Green, 1832)		X		1	
38. <i>Toxolasma parvus</i> (Barnes, 1823)		X			1
39. <i>Ligumia recta</i> (Lamarck, 1819)	X	X	X	6	50
40. <i>Lampsilis teres forma teres</i> (Rafinesque, 1820)	X	X	X	3	1
41. <i>Lampsilis teres forma fallaciosa</i> (Smith, 1899)	X	X	X	535	8
42. <i>Lampsilis radiata luteola</i> (Lamarck, 1819)	X	X		64	
43. <i>Lampsilis higginsii</i> (Lea, 1857)	X	X		1	14
44. <i>Lampsilis ventricosa</i> (Barnes, 1823)	X	X	X	8	35

* = subfossil only

B₁ = Collection made by Baker in 1904 (Baker, 1905)

S = Collection made by Shimek prior to 1921 (Shimek, 1921)

B₂ = Collection made by Baker in 1920-22 (Baker, 1928)

E = Collection made by Ellis in 1930-1931 (van der Schalie, 1950)

H = Collection made by Havlik in 1976 (this study)

TABLE 2

SUMMARY OF NAIAD SPECIES RECORDED
FROM THE MISSISSIPPI RIVER IN THE VICINITY
OF PRAIRIE DU CHIEN, WISCONSIN

	1905	1921	1920-22	1930-31	1976-77
Family Margaritiferidae					
<i>C. monodonta</i>	1	1	1	0	0
Family Unionidae					
Subfamily Anodontinae	6	8	4	5	5
Subfamily Ambleminae	14	16	12	11	11
Subfamily Lampsilinae	13	18	10	15	16
TOTAL SPECIES	34	43	27	31	32

appears to have lost only 27 per cent of its original species. Several of the missing Mississippi species seem to have been poorly established here even before the impact of modern man. Even so, there is cause for concern. Studies are currently being made by several state and federal agencies to find ways to improve the river habitat for the benefit of this valuable resource and, both directly and indirectly, for the benefit of man himself.

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WOOD, MOLLUSKS, AND DEEP-SEA FOOD CHAINS

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It is now recognized (Turner 1973, Wolf 1976, Sanders 1977, Wirsén and Jannasch 1976, Jannasch and Wirsén 1977) that woody plant material reaching the deep sea is readily decomposed through the activity of wood boring bivalves (subfamily Xylophaginae, Family Pholadidae) and that they are the most important organisms involved in converting this refractory material into an available food source for other organisms. However, this left questions concerning: 1) the amount of wood reaching the deep sea, 2) its importance as a source of nutrient, 3) the effect of a continuous food supply on community size, structure and diversity and, 4) the influence of this primary food source on the growth and reproductive rates of deep sea organisms.

It is also generally agreed that: 1) the rate and stability of primary production is ultimately responsible for regulating the number of species in a community (Paine 1966), 2) that a stable population of primary consumers allows for increased diversity of detritus feeders and predators (McArthur and Levins 1964, Menge and Sutherland 1976), and 3) that the relationship between productivity and diversity (usually obscured by other parameters in most communities) can best be studied in physically stable environments (McArthur 1972, Dayton 1974, Rex 1976).

The most stable environments known are found in caves, the antarctic benthos below 30 m and in the deep sea, but of these, only the deep sea is considered to lack marked annual pulses (Dayton 1974). Thus, the deep sea should be the best area to test experimentally the relationship between primary productivity and diversity, and to gain insight into the compatibility of the stability-time hypothesis (Sanders 1968, 1969, Grassle and Sanders 1973) and the predation theory (Dayton and Hessler 1972).

There is no primary production in the deep sea (except possibly at the hot submarine springs (vents) off the Galapagos Islands where bacteria are capable of oxidizing the hydrogen sulfide in the spring water (Jannasch and Wirsén (1977)) because there is no light to support photosynthesis.

However, wood, a refractory product of photosynthesis, does reach abyssal depths in sufficient quantity to support an entire subfamily of obligate deep sea wood borers. The activity of these borers rapidly converts the wood to an available food source in the form of fecal pellets for detritus feeders; larvae and adult borers for predators; dead remains of all these organisms for scavengers; and finally free swimming larvae and divided debris in the water column for filter feeders (Turner 1973).

Paine (1966) and others have stated that stable environments with adequate primary productivity give rise to trophically complex communities with predation being the most important interaction governing diversity. If this is true, then the regular placement of wood in the deep sea (i.e. building a wood island) should increase diversity at the site with the greatest increase being among the predators.

To test this hypothesis three "wood islands", each consisting of 12 one foot cubes of spruce were placed at the following locations:

1. Deep Ocean Station-1 (DOS-1) 110 miles S. of Woods Hole, Mass. 39° 46' N; 70° 41' W in 1830 m.

2. Deep Ocean Station-2 (DOS-2) 190 miles SE of Woods Hole, Mass. 38° 18.4' N; 69° 35.6' W in 3506 m.

3. Tongue of the Ocean Bahama Islands (TOTO, Tower 3) 24° 53.2' N; 77° 40.2' W in 2066 m.

The "islands" which will remain on the bottom for at least 5 years, are surrounded by small wood panels, 24" x 5" x 1" (Figs. 1 and 2). The panels are pointed at one end to facilitate pushing them into the mud and enclosed in mesh bags (mesh size 10 x 5 mm) to ensure retrieval of the pieces should the panel be so riddled that it falls apart. Whenever the bottom stations are visited, panels are collected and new ones put in their place. Usually, panels exposed more than 1½ years are completely riddled (Figs. 3 and 4). On April 19, 1975, (ALVIN dive 552), we collected the first of these panels. They had been exposed in the Tongue of the Ocean on January 21, 1974. As ALVIN approached the site we noticed increased numbers of

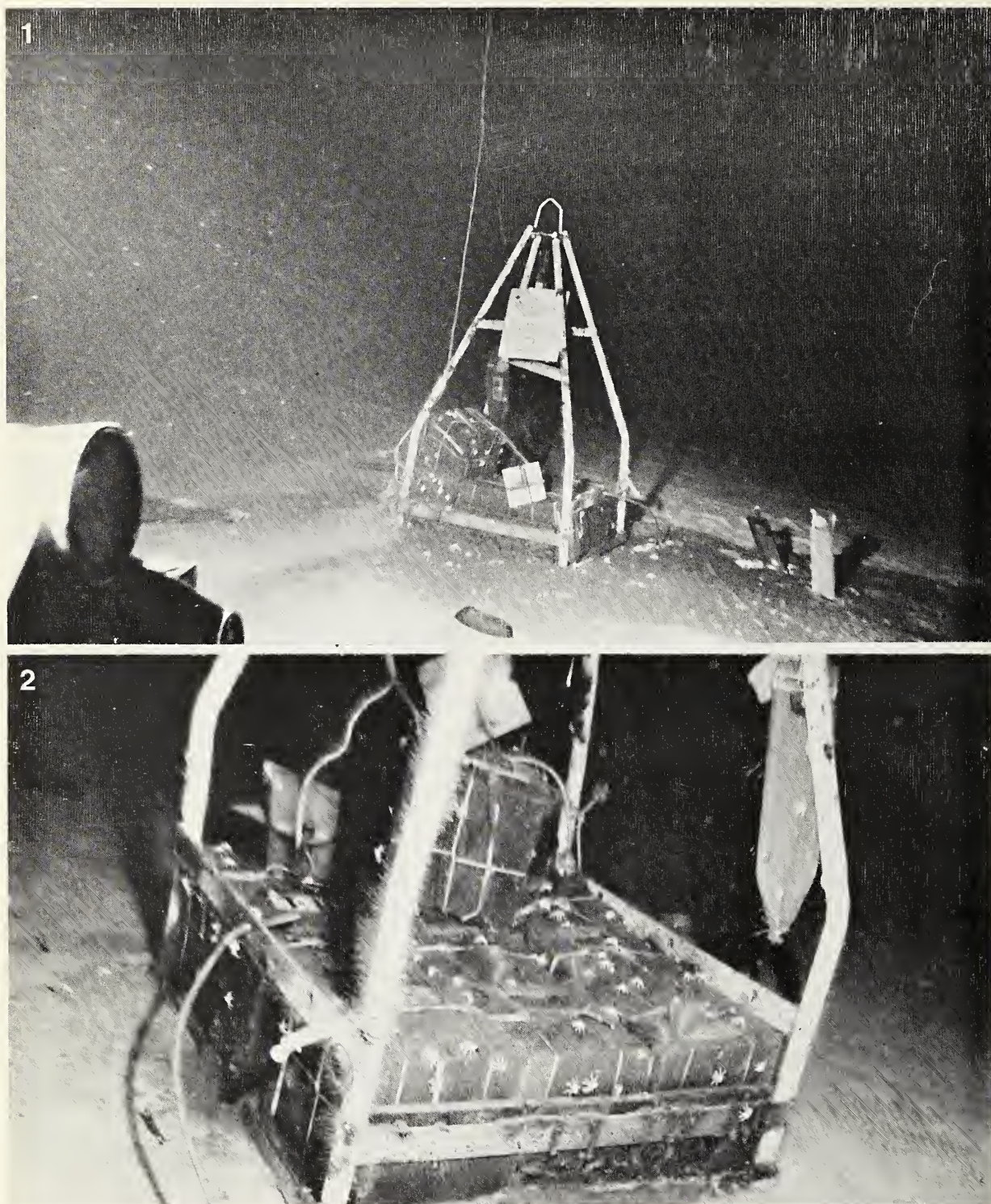


Fig. 1. Wood Tower on bottom at TOTO sta. 3 (24 degrees 53.2' N; 77 degrees 40.2' W) in 2066 m. Two wood panels can be seen to the right of the tower, and a holothurian at the lower center of the picture. Note the dark stain surrounding the "island" and extending out to the left in the direction

of the current. The arm of DSRV/ALVIN can be seen in the left hand corner of the picture.

Fig. 2 Close up of the "wood island" to show the large number of galatheid crabs on the wood blocks and the thick growth of hydroids on the frame.

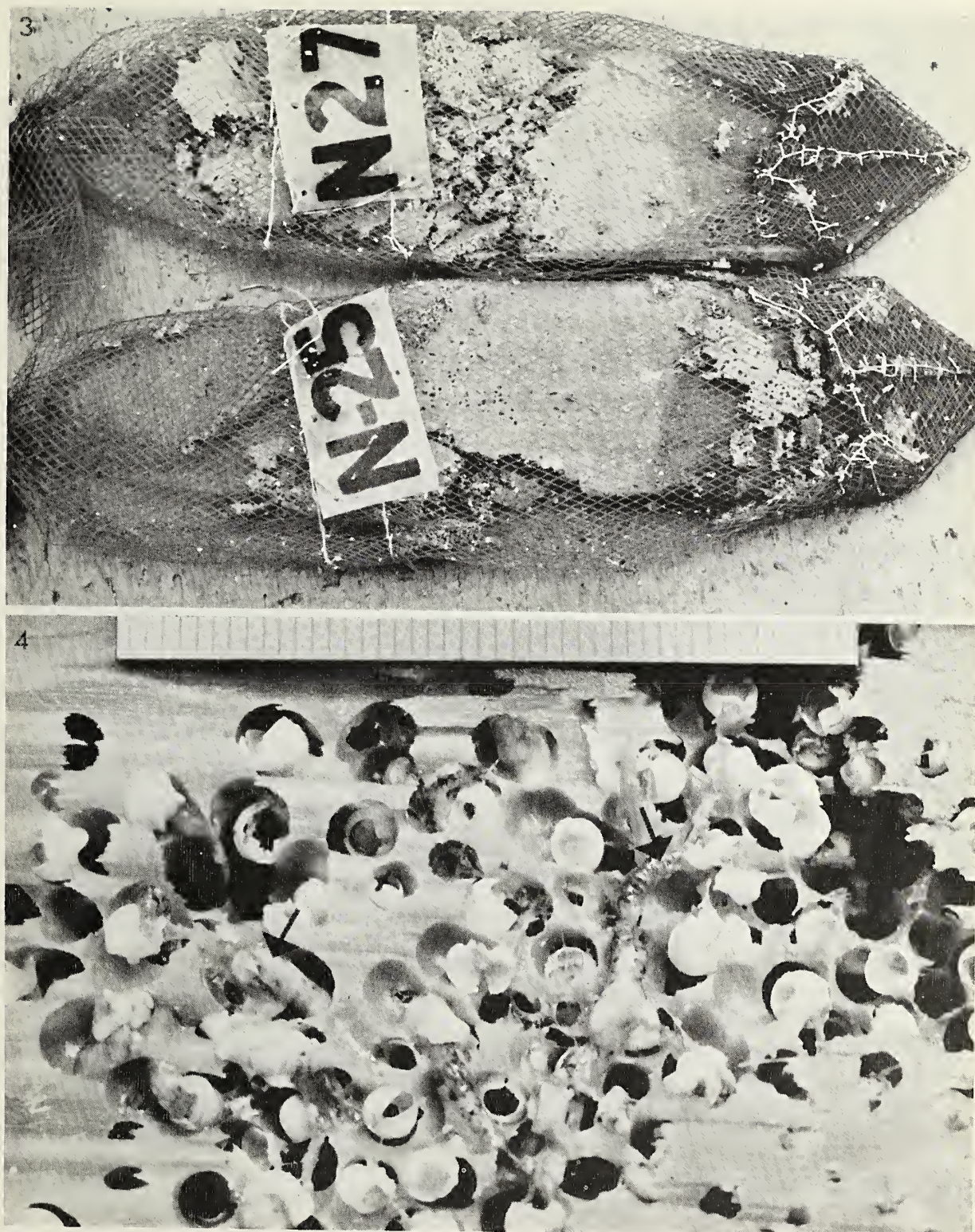


Fig. 3 Two riddled and disintegrating panels that had been exposed at the northern station (DOS-1) from August 3, 1975 to June 16, 1976.

Fig. 4 Close up of panel with surface removed to

show heavy concentration of borers. Arrows point to polychaete worms in the burrows that were feeding on fecal pellets and dead *Xylophaga*. Scale is in millimeters.

galatheid crabs. The wood island and panels were covered with them (Fig. 2). Most of the crabs fell off as the panel was picked up, but 12 specimens had grown up inside the mesh bag and were carried to the surface (Fig. 5). The smallest specimen (8 mm in length) was actually in an empty *Xylophaga* burrow. The remaining specimens were between 24 and 45 mm in length. The crabs obviously found sufficient food in or on the wood to keep them there and to allow them to grow at a fairly rapid rate. The first young crabs to find the wood may have fed on newly settled *Xylophaga* larvae. This might explain the patchy distribution of the borers in the panel. The wood was exposed for 15 months, but a month or two could have elapsed (based on some short term tests at this site) before any significant settlement occurred. The borers then had to grow to sufficient size to attract predatory worms and crabs and this might require a month or more. On the basis of these facts, I would postulate that, given sufficient food, the crabs could grow at a rate of about 5 mm a month.

The panels contained *Xyloredo nooi* Turner and 2 species of *Xylophaga* (Fig. 4). Specimens of *X. nooi* had valves 5 mm in length and burrows 50 mm in length. When compared with growth rates given by Turekian et al. (1975) and Sanders (1977), both the primary consumers and the most conspicuous predator showed unusually rapid growth for the deep sea.

Xyloredo make a calcareous lining to their burrows, but the two species of *Xylophaga* line the posterior end of their burrows with compacted fecal pellets. In all burrows containing dead *Xylophaga*, these fecal pellets lined harbored from one to three capitellid worms while crysotellid, hesionid and polynoid worms were often found between the valves obviously feeding on the *Xylophaga*. Examinations of stomach contents of galatheid crabs produced setae of polychaetes, a nematode, sponge spicules and minute particles of wood comparable to those in the caecum of the *Xylophaga*, suggesting that the crabs were feeding on both wood borers and the worms.

Results from the northern stations (DOS-1 and DOS-2) proved similar to those in the Tongue of the Ocean. Panels exposed from August 3, 1975 to June 16, 1976, at DOS-1 and from September 5, 1975 to August 13, 1976 at DOS-2 were crumbling as a result of borer activity. The burrows of dead *Xylophaga* contained capitellid and crysotellid worms. On the surface of the wood, as well as in

the burrows, were numerous large polynoid worms. Brittle stars and small sea urchins, *Echinus* sp., were also on the surface of the panels. *Xyloredo ingolfia* Turner was the predominant borer at both stations. *Xylophaga* was more abundant in the upper part of the panels and it was in the fecal pellet linings of these burrows where the capitellids were found. Galatheid crabs were not found at the shallow station, DOS-1, but did occur at DOS-2.

Enclosing the panels in mesh bags allows ALVIN to pick up the crumbling wood and carry it to the surface. However, it soon became obvious that to understand the food web based on wood, it was necessary to protect the panels from washing on their way to the surface. Special retrieval boxes were first used in the Tongue of the Ocean in May 1977. Two retrieval boxes were carried on the ALVIN basket, one fitted with plastic bags containing gluteraldehyde which were punctured when the box was closed, thus flooding the contents and preserving the specimens on the bottom under ambient pressure and temperature. Panels in the other box were not preserved but were brought to the surface unwashed and in much better condition than previously.

These results far exceeded our previous collections and expectations and constitute the first documented food chain in the deep sea that is not based solely on stomach contents. It demonstrates the importance of retrieving samples without washing through 2000 to 3000 m of water. Far more work has to be done on dissecting the panels and working up the material before a detailed report can be written.

The area around the island was stained a yellow brown resulting from the spread of the fecal pellets of the animals in and on the wood (Fig. 1). Box cores taken at varying distance from the wood islands by J.F. Grassle (personal communication) showed that those close to the island have larger numbers and variety of organisms than those taken at 5 meters distance. This suggests that fecal pellets, "trapped" larvae of the wood borers, etc., resulting from the activity of the wood based community, enrich the bottom sediments and contribute to the size and richness of the infaunal community.

Study of this material to date continues to support my hypothesis and shows that; 1) wood is an important source of nutrient in the deep sea, 2) the wood-boring bivalves (*Xylophaginae*) are the most important organisms involved in making this refractory food source available, 3) a food chain

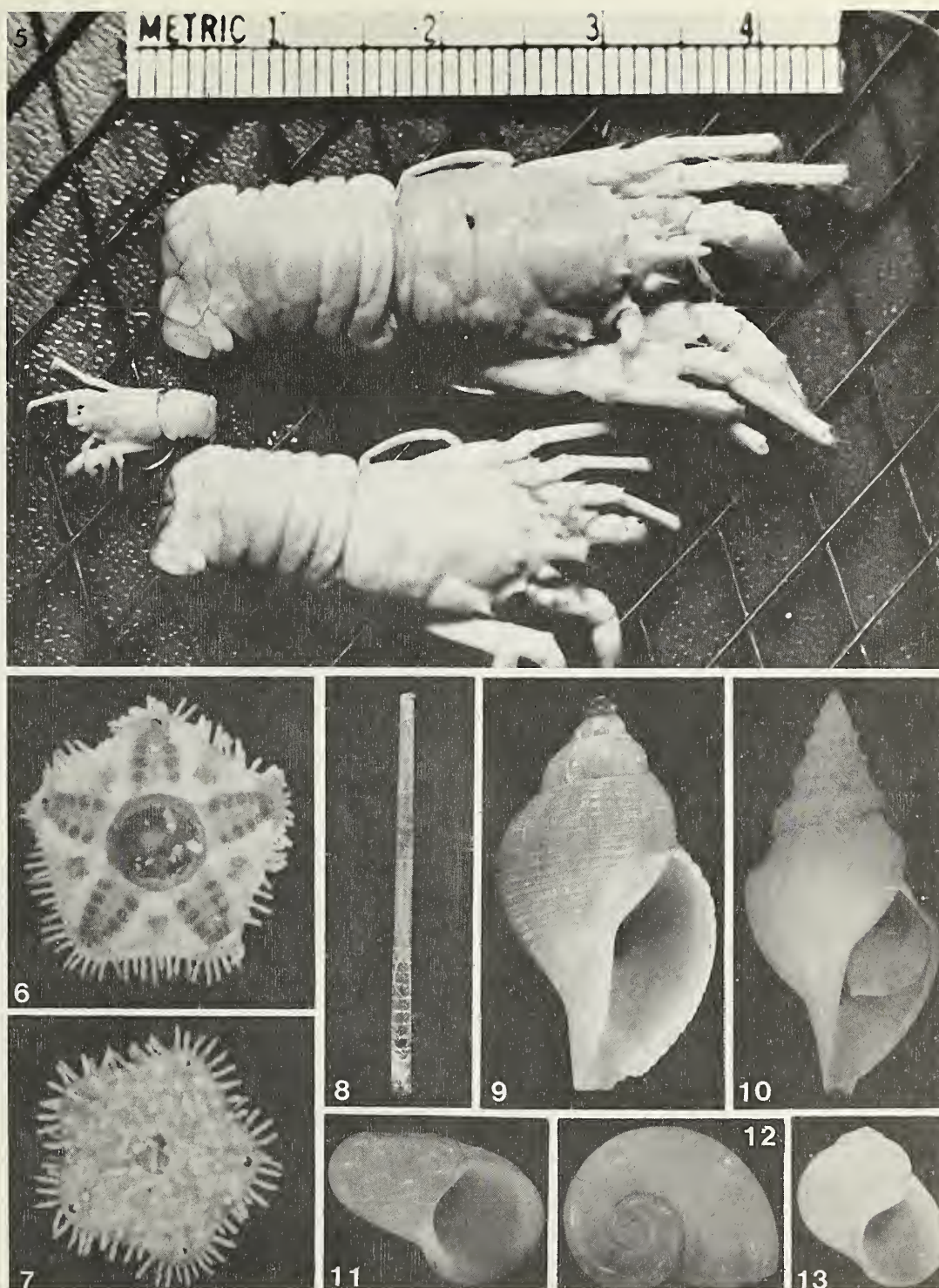


Fig. 5. Galatheid crabs brought to surface with panel enclosed in mesh bag and submerged in the Tongue of the Ocean from January 21, 1974 to April 19, 1975.

Figs. 6-13. Other predatory invertebrates found on wood panels exposed for a year in the Tongue of the Ocean: Fig. 6—ventral and Fig. 7—dorsal views

of young starfish. Fig. 8—*Hyalinoecia* sp. (90 mm long). Fig. 9—*Daphnella pompholyx* Dall (9 mm long). Fig. 10—*Pleurotomella bairdii* Verrill and Smith (31 mm long). Fig. 11—apertural and Fig. 12—apical views of *Cyclostrema pompholyx* Dall (4 mm in greatest diameter). Fig. 13—*Ganessa* sp., probably *pruinosa*.

based on wood and xylophagids is composed of several species of polychaete worms, the first to appear being the well-known opportunists, the capitellids. Also included in this food web are the crysotellid and polynoid worms, predatory gastropods, galatheid crabs, echinoderms and probably fish, 4) fouling communities which are dependent on hard substrates for attachment (hydroids, sponges, sea anemones) as well as surface living browsers (patellid gastropods, chitons) and filter feeders (hydroids, sea anemones) benefit from the wood based community and contribute to its diversity.

The results also support the Hutchinson (1959) and Paine (1966) hypothesis which states that, given a stable environment and adequate primary productivity, diversity should increase, particularly among predators. As shown in Table I, the greatest diversity in our wood based community was among the polychaetes and predatory gastropods.

These results also suggest that a constant and abundant nutrient source (in this case wood) may well contribute to the increased growth and repro-

ductive rates of infaunal and "fouling" species. According to Turekian et al (1975) and Grassle and Sanders (1973) most infaunal mollusks are very slow growing, live to a great age and have a very low reproductive rate. By running long term "wood island" experiments at the DSRV/ALVIN bottom stations, I hope to gain insight into the relationship between nutrient levels, rates of growth and reproduction of both epifaunal and infaunal deep sea organisms.

Recent observations have shown that "large parcels" of fish arriving on the sea floor are rapidly located and consumed by mobile benthic megafauna (Isaacs, 1969). The nutrients from these "parcels" are then presumably disseminated over the ocean floor in the form of fecal pellets (Dayton and Hessler, 1972) making it impossible to experimentally test the effect of nutrient enrichment on infaunal species. Conversely, it takes years for the borers to consume a "wood island" and it is evident from my experiments to date, that the associated fauna of invertebrates gradually increases. Therefore isolated "wood islands" placed on the abyssal plain should be an ideal way of testing the relationship between productivity and diversity in a physically stable environment.

Table 1.

Number of species found on TOTO panel submerged 1 year

D = detritus feeder
F = filter feeder

P = predator
S = scavenger

Group	No. of species	Feeding type
Porifera	1	F
Hydrozoa	2	F
Anthozoa	2	F
Turbellaria	1	P
Nematoda	1	P
Polychaeta	6	1 D, 5 P
Polyplochophora	1	B
Gastropoda	11	9 P, 2 B
Bivalvia (non borers)	2	F
Bivalvia (wood borers)	3	wood, F
Pycnogonida	1	P
Amphipoda	2	S, P
Isopoda	1	S, P
Ostracoda	1	F
Copepoda	1	F
Decapoda (galatheid crab)	1	P, S
Ophuroidea	2	S, P
Crinoidea	1	F
Holothuroidea	1	D
Total species:	41	

SUMMARY

Experiments to test the hypothesis that wood is an important source of nutrients and contributes to diversity in the deep sea were conducted, using the DSRV/ALVIN. Wood panels and "islands" composed of 12 cubic feet of wood were set out at three sites in 1830-3600 m. The results indicated: 1) wood-borers (Xylophaginae) are the most important organisms involved in recycling the wood, 2) the food chain based on wood and xylophagids includes capitellid, crysotellid, and polynoid worms, predatory gastropods, galatheid crabs and probably fish.

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GENETIC RELATIONS OF DEEP-SEA WOOD-BORERS

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INTRODUCTION

Bivalves of the subfamily Xylophaginae (family Pholadidae) are mostly deep-sea wood borers, though a few species extend into the sublittoral (Turner, 1966). Unlike other pholad wood-borers, these organisms have a wood-storing caecum and utilize wood as food. Purchon (1941) suggested that this subfamily is sufficiently distinct from the rest of the Pholadidae to justify the family status.

He proposed that the Xylophaginae and the Teredinidae (shipworms) both arose from a common ancestral wood-boring pholad by adopting wood as a nutritive source in addition to its previous use for protection.

Other workers have stressed anatomical and shell-morphological characters to relate the Xylophaginae with the pholads (Knudsen, 1961; Turner, 1966, 1967). Nonetheless this subfamily

exhibits remarkable convergence with teredinids, presumably because wood-boring and consumption exerts stringent and similar constraints on wood-utilizing bivalves. Tereidid and xylophagid wood-borers converge in possessing 1) a wood-storing caecum, 2) remarkably similar shell morphologies, 3) similar modes of boring, and 4) a calcareous lining of the burrow (at least in one xylophagid genus (*Xyloredo*)) (Turner, 1967, 1972, 1973). Tereidids, however, have 1) pallets, used to plug the burrow entrance when an animal is disturbed, 2) apophyses, extensions of the valves which provide additional attachment surfaces for the large pedal muscles used in boring, and 3) the visceral mass extending well beyond the posterior adductor muscle, with the gills elongated to nearly the base of the pallets. Xylophaginae lack pallets and apophyses, and neither the visceral mass nor the gills extend beyond the posterior adductor muscle. They do have a dorsal plate, the mesoplax. Other pholad subfamilies (Martesiinae; Pholadinae) have apophyses, but, if they are wood-borers, they do not use the wood for nutrition (Turner, 1955). Wood-boring bivalves diverge ecologically, with the Tereididae and Martesiinae being exclusively littoral and sublittoral, and teredinids not invading new wood at depths greater than 200 meters (Tipper, 1968; Turner, 1966, 1973). Most Xylophaginae are bathyal in distribution, though a few species (i.e., *Xylophaga atlantica*, *X. globosa* and *X. dorsalis*) occur in high latitude, sublittoral waters (Turner, 1955; Knudsen, 1961; DePalma, 1969).

We have investigated relatedness among selected species within the families Pholadidae and Tereididae using allozymic characters. This permits phylogenetic comparisons at a more basic level (i.e., closer to the hereditary DNA material) than do classical systematic methods (Avice, 1974). Species which are members of the same family should show higher levels of genetic similarity to each other than to species in other families.

METHODS AND MATERIALS

Table I summarizes pertinent information concerning the species compared in this study, and how samples were obtained.

Horizontal starch-gel electrophoresis (Brewer, 1970) was used. The routine buffer system was a lithium hydroxide-Tris-citrate discontinuous system (Selander et al, 1969). Other buffer systems pro-

duced improved resolution for some enzymes; however, once the mobility patterns were understood, LiOH-system gels provided reliable scoring. Staining recipes were adapted from Shaw and Prasad (1970) or Brewer (1970).

Observed versus expected proportions of heterozygotes were compared by the statistic,

$$D = \frac{H_o H_e}{H_e}$$

where H_o is the observed number of heterozygotes, and H_e is the number expected, assuming Hardy-Weinberg equilibrium conditions, and using the observed gene frequencies (Ayala, 1976).

Nei's (1972) index of genetic similarity, I , was calculated from allozyme data to assess genetic relatedness among the species.

RESULTS

Twenty-two loci were resolved in *Lyrodus pedicellatus* (Quatrefage) and *Xylophaga* sp., 18 each in *Martesia striata* (Linnaeus) and *Xylophaga atlantica* Richards, and 17 in *Xyloredo ingolfia* Turner (Table II). Genetic variability found among the species investigated is summarized in Table III.

The percentage of loci which were segregating two or more alleles varied from 50 per cent in *Lyrodus pedicellatus* to 33 per cent in *Xylophaga atlantica*. *Xyloredo ingolfia* exhibited levels of polymorphism almost as high as *L. pedicellatus* (47.1; 50.0 per cent respectively). Both these species were polymorphic at 37% of the enzymes studied (Table II) when the next most polymorphic species (*Martesia striata*—44.4 per cent) was compared with *L. pedicellatus*, both had polymorphic loci at 32 per cent of the enzymes examined. The least and most polymorphic species (*Xylophaga atlantica*—33.3 per cent; *L. pedicellatus*—50.0 per cent, respectively) covaried for 56 per cent of the enzymes studied.

Of the enzymes examined, 21 per cent were polymorphic in each of the five species, 11 per cent in species compared three at a time, 5 per cent in pair-wise comparisons, and 21 per cent in only one species. An identical number exhibited polymorphism in only one species of the five, i.e., are species-specific. *Martesia striata* possessed two (SOD, XDH), and *Lyrodus pedicellatus* and *Xylophaga* sp. one each (AO and α -GPDH, respectively). Intermediate species groupings (2, 3, and 4-way) produced few enzymes with polymorphic

Table I.

Locations and dates of samples of wood-boring bivalve species utilized in this study. Additional information is provided on each species' characteristic depth and geographic range, and its use of wood. *Xylophaga atlantica* was collected during routine dredging operations by National Marine Fisheries' R/V Albatross IV. Samples of the other two xylophagids were removed from pine boards exposed for one year at the Woods Hole Oceanographic Institution's permanent Deep Ocean Station 2. These were recovered using the DSRV Alvin.

Taxonomic affinities	Dates and sites of samples	Recorded depth range	Geographic range	Uses wood for
Family Pholadidae	May 1976, littoral			
Subfamily Martesiinae	from mangrove wood	littoral	Circum-tropical and warm temperate	protection
<i>Martesia striata</i>	South Florida			
Subfamily Xylophagainae				
<i>Xylophaga atlantica</i>	March 1976, 177 m, off New England (41°46' N, 69°07' W)	temperate continental shelf	Western Atlantic, Canada to Virginia	protection and nutrition
<i>Xylophaga</i> sp.	June 1976, 3650 m, off New England (38°14.4' N, 69°35.6' W)	deep sea	poorly known, probably North Atlantic basin	"
<i>Xyloredo ingolfia</i>	"	"	"	"
Family Teredinidae				
Subfamily Teredinidae				
<i>Lyrodus pedicellatus</i>	Taken as needed from large lab culture, original isolate from Long Beach, CA, 1966	littoral	Circum-tropical and warm temperate	"

loci.

Heterozygosity estimates (i.e., the percentage of heterozygous loci expected in the genome of a randomly sampled individual) were calculated by averaging heterozygosities from each individual locus. These ranged from 0.233 (*Lyrodus pedicellatus*) to 0.155 (*Xylophaga atlantica*) and followed the order established by the percent poly-

morphism measure (Table III). A deficiency of heterozygotes was observed in the samples of each species; unfortunately class sizes were too small to permit chi-square evaluation (Crow and Kimura, 1970). *Lyrodus pedicellatus* exhibited the greatest deficiency; *Martesia striata* the least.

Comparing species by use of Nei's index showed that species of Xylophagainae are much

Table II.

Monomorphic and polymorphic loci for each protein system studied. M = monomorphic; P, polymorphic. For a locus to be considered polymorphic, the frequency of the major allele could not exceed 0.95. The prefixed number is the number of loci per category (monomorphic; polymorphic) per enzyme. In parentheses are the numbers of alleles found at that locus. Blanks indicate either no activity for the enzyme, or unscorable results.

Species

Enzyme	<i>Martesia striata</i>	<i>Xylophaga atlantica</i>	<i>Xylophaga sp.</i>	<i>Xyloredo ingolfia</i>	<i>Lyrodus pedicellatus</i>
Acid phosphatase (AcP)	1 (M)	-	-	-	-
Alcohol dehydrogenase (ADH)	1 (M)	1 (M)	1 (M)	1 (M)	-
Aldehyde oxidase (AO)	-	-	1 (M)	1 (M)	2 (M) 3 1(P-3)
Alkaline phosphatase (AKP)	1 (M)	-	-	-	-
Esterase (α and β) (Est)	2 (P-3;3)	2 ¹ (M) 1 (P-2)	2 ¹ (M) 1 (P-3)	2 (P-3; 3)	3 (P-2; 4;2)
General protein (GP)	-	3 (M)	3 (M)	3 (M)	3 (M)
Glyceraldehyde-3-phosphate dehydrogenase (GA-3-PD)	-	-	2 ¹ (M) 1 (P-2)	2 (M)	1 (M)
α -Glycerophosphate dehydrogenase (α -GPDH)	-	-	2 ¹ (M) 1 (P-2)	2 (M)	1 (M)
Hexokinase (HK)	2 ¹ (M) 1 (P-2)	-	-	-	2 (P-3; 3)
Isocitrate dehydrogenase (ICD)	2 (M)	2 ¹ (M) 1 (P-2)	2 (M)	1 (P-3)	1 (P-2)
Leucine amino peptidase (LAP)	1 (P-3)	1 (P-3)	1 (P-4)	1 (P-3)	1 (P-4)
Malate dehydrogenase (MDH)	3 (M)	3 (M)	3 ¹ (M) 2 (P-2)	3 ¹ (M) 2 (P-2;3)	3 ² (M) 1 (P-2)
Octanol dehydrogenase (ODH)	-	-	-	-	1 (M)
Phosphoglucosmutase (PGM)	1 (P-2)	3 ¹ (M) 2 (P-3;2)	3 ¹ (M) 2 (P-2;3)	2 ¹ (M) 1 (P-3)	1 (P-2)
Phosphohexoseisomerase (PHI)	1 (P-3)	1 (P-3)	1 (P-2)	1 (P-2)	1 (P-2)
Sorbitol dehydrogenase (SDH)	-	-	1 (M)	-	1 (M)
Succinate dehydrogenase (SuDH)	-	-	1 (M)	-	-
Superoxide dimutase (SOD)	1 (P-2)	-	-	-	-
Xanthine dehydrogenase (XDH)	1 (P-2)	1 (M)	1 (M)	-	-

more genetically similar to each other than they are to *Martesia striata* or *Lyrodus pedicellatus* (Table IV). The two *Xylophaga* species are more similar to each other than either are to *Xyloredo ingolfia*.

DISCUSSION

Comparisons of suites of allozymic polymorphisms between wood-boring bivalves indicate little commonality. Either wood-boring demands a

Table III.

Summary of genetic variability information based on electrophoretic analysis. Percent polymorphism is the percentage of loci resolved which were segregating for two or more alleles. Minimum allele frequency for a locus to be considered polymorphic was 5%. Percent heterozygous loci per individual was calculated by averaging over all loci the observed heterozygosity at each locus (Ayala, 1976). The statistic "D" is the deficiencies of heterozygotes in the samples.

Species	Sample size	Number of loci studied	Percent Percent polymorphic loci	Percent heterozygous loci per individual	D
<i>Martesia striata</i>	24	18	44.4	0.231	-0.076
<i>Xylophaga atlantica</i>	27	18	33.3	0.155	-0.110
<i>Xylophaga</i> sp.	21	22	36.3	0.156	-0.099
<i>Xyloredo ingolfia</i>	31	17	47.1	0.209	-0.179
<i>Lyrodus pedicellatus</i>	23	22	50.0	0.233	-0.247

Table IV.

Genetic similarity comparisons among wood-boring bivalve species ("I"; Nei (1972)).

	<i>Xylophaga atlantica</i>	<i>Xylophaga</i> sp.	<i>Xyloredo ingolfia</i>	<i>Lyrodus pedicellatus</i>
<i>Martesia striata</i>	0.107	0.093	0.059	0.021
<i>Xylophaga atlantica</i>		0.487	0.230	0.003
<i>Xylophaga</i> sp.			0.238	0.019
<i>Xyloredo ingolfia</i>				0.088

somewhat different biochemical approach for each species, or at least some of the allozymic polymorphisms do not correspond to environmental pressures. The selective maintenance of allozymes is currently a greatly debated subject in population genetics (Ayala, 1976). Probably this question will eventually have to be decided for each enzyme system separately.

Comparisons of polymorphic enzymes and the distribution for each among the species examined indicate that there are two general classes. Some enzymes (36 per cent of those enzymes exhibiting polymorphism) seem characteristically polymorphic in wood-boring bivalves, while others (again 36 per cent) show species-specific polymorphism. As few enzymes fell in intermediate rankings, this suggests that allozymic characters may be useful for species identification, using species-diagnostic

loci.

Though interesting, the information on genetic variability must be interpreted cautiously due to small sample sizes. The trends observed, however, are intriguing. The greatest degree of heterozygote deficiency was observed from *Lyrodus pedicellatus*. These animals were taken from a laboratory population begun in 1966 to which additional material has been added from time to time. However, the population has also experienced several crashes in numbers due to failure of the heated seawater system. This population may be somewhat inbred as a result (Lewontin and Hubby, 1966).

The values of *D* also correlate with what is known of the reproductive biology of the species studied. *Lyrodus pedicellatus* (*D* = -0.247) releases non-feeding pediveligers which settle quickly. It

also shows a proclivity for self-fertilization (Eckelbarger and Reish, 1972; T. Cole, unpublished data). Fertilization is external in *Martesia striata* ($D = -0.076$) (Turner and Johnson, 1971; Boyle and Turner, 1976). *Xylophaga atlantica* reared in the laboratory releases fertilized eggs, suggesting internal fertilization (Culliney and Turner, 1976). Purchon (1941) demonstrated that *Xylophaga dorsalis* possesses a seminal vesicle, and has an accessory genital organ, which he proposed functions to retain sperm produced by these protandric hermaphrodites when in the male phase. Presumably the bathyl species of Xylophaginae studied here (*Xylophaga* sp. and *Xyloredo ingolfia*) also possess these organs; however, at present little is known of their reproductive biology. Most deep-sea bivalves produce demersal larvae (Ockelmann, 1965), but effectiveness of this type of larvae in gene flow is unknown.

The current phylogenetic position of the Xylophaginae is not affected by this investigation because on an electrophoretic basis this subfamily is no more closely related to *Martesia striata*, another wood-boring pholad, than to *Lyrodus pedicellatus*, a teredinid. Interpretation of similarity values, however, is difficult due to a lack of comparative data and because the most extensive data on this subject is based on drosophilid flies. I values calculated for the two species of *Xylophaga* are typical of sibling *Drosophila* species relatedness (Ayala, 1975). Sibling species are defined as morphologically indistinguishable forms, which produce sterile hybrids for at least one reciprocal cross. A *Drosophila*-based scale would indicate congeneric relatedness when either *Xylophaga* species are compared with *Xyloredo ingolfia*. Based on the limited work of this type conducted on other invertebrate taxa, a comparison of *Xylophaga* species with *Xyloredo ingolfia* would place them in different genera (Ayala, 1965), agreeing with present-day classification. Recent comparisons made on three species of British *Littorina*, give values of 0.600 for pairwise species comparisons. On the *Drosophila* scale this again is at sibling species level, but with data from other invertebrates it indicates closely related species, which is more realistic. This suggests that extrapolations from drosophilids to other invertebrates may not be useful. At present it is impossible to interpret values such as those found when the species of Xylophaginae are compared with *Martesia striata* or *Lyrodus pedicellatus*, or when *M.*

striata and *L. pedicellatus* are compared with each other. Other subfamilies of the Pholadidae, particularly the Jouanettinae (the other pholad subfamily which lacks apophyses) now need to be compared with Xylophaginae to study further the evolution of wood-boring bivalves.

SUMMARY

An electrophoretic analysis of wood-boring bivalve species of two families (Pholadidae; Terebinidae) to date supports existing taxonomies and indicates members of the pholad subfamily Xylophaginae are approximately equally distinct genetically from other wood-boring forms. Further research is needed before the significance of this distinctiveness can be fully assessed.

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ASPECTS OF THE FUNCTIONAL MORPHOLOGY
OF THE MANTLE/SHELL AND MANTLE/GILL COMPLEX
OF *CORBICULA* (BIVALVIA: SPHAERIACEA: CORBICULIDAE)

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The increasing numbers of the introduced Asian clam, *Corbicula*, in U.S. river bottoms have gradually come to concern biologists (Sinclair and Isom, 1963 and Sinclair, 1971). In large rivers of the Ozarkian drainages there has been a rich fauna, abundant and varied, of indigenous mussel species (van der Schalie and van der Schalie, 1959). A recent study of the Arkansas River benthos (Kraemer, 1976) revealed that the salient molluscan component was not the indigenous mussel assemblage, but rather *Corbicula*. Moreover, the incidence and abundance of this single

mollusk genus exceeded that of the entire benthic arthropod component.

The rate of spread of *Corbicula* has puzzled investigators (Mattice, 1975). Is *Corbicula* functioning as competitor and/or as an opportunist as it spreads rapidly through such heavily managed waterways as the Arkansas River? A clue may lie in observations of living *Corbicula* which indicate that this small clam (Arkansas specimens in our collections are seldom more than 3 cm long) can travel horizontally through the substrate at a rate of nearly 250/cm/hr., even over bare substrate, a

remarkable speed for a freshwater bivalve. The animal's shoveling movements resemble those of larger bivalves (Morton, 1964). *Corbicula*, body and shell, has the shape of a comparatively high, narrow triangle (like its fellow Sphaeriaceans, the sphaeniids or "pill" clams), and thus has a fairly short horizontal axis. *Corbicula* carries its muscular siphons at almost a right angle to the substrate, while the typical river mussel, whose siphons are merely modified, unfused portions of the posterior mantle edge, carries siphons parallel to the substrate in normal locomotion (Kraemer, 1970).

The foregoing observations prompted a study of the functional morphology of the *Corbicula* mantle complex. Materials and methods employed are identical with those described elsewhere (Kraemer and Lott, 1977).

The saddle-shaped bilobed mantle of bivalves is marked dorso-medially by an isthmus positioned between the dentition of the lateral shell valves; and the tissue of the isthmus secretes the inner layer of the ligament. At its margin, each lobe of the mantle shows 3 folds. Yonge (1957, pp. 152-3) reviews the organization and function of these folds:

The outer fold (O) secretes the two outer layers of the shell. Its outer surface (Oc) secretes the outer calcareous layer (oc) of the valves and the outer ligament layers while its inner surface (oi) secretes the periostracum (p) that, at any rate, initially covers all areas of the shell... The middle fold (M)...is largely receptive in function... The inner fold (I), often much the largest, is characteristically mobile...contains radial muscle attached to the shell along the pallial line, and between these, circular muscles.

OBSERVATIONS

Gross morphology of mantle, shell and posterior adductor muscle:

The mantle of *Corbicula* is held in a vise-like grip by the strong cardinal teeth and heavy, serrated anterior and posterior lateral teeth of the valves (Fig. 1A). Superfamily relatives of *Corbicula*, the small, indigenous "pill" clams, lack such dentition (Fig. 1B). Even when removed from its shell, the mantle of *Corbicula* remains imprinted with a series of "toothmarks" where it was held in the grip of the lateral teeth, (Fig. 2).

Both anterior and posterior adductor muscles lie in cavities surrounded by, but relatively free from the mantle. Once freed from its insertions on the shell valves just under the distal ridge of the lateral teeth, the posterior adductor muscle may simply fall out of its mantle-lined "hole" and lie in the dissecting dish, like a pale, slightly asymmetrical, microscopic cigar. Within the membrane-lined "hole" (Fig. 2) the fused visceral ganglion is

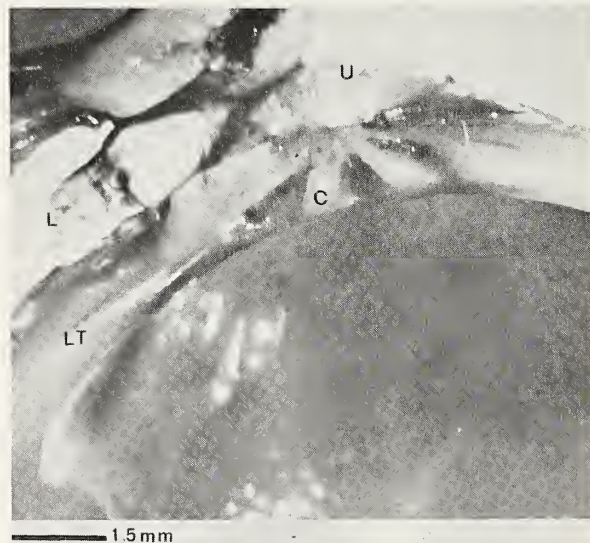
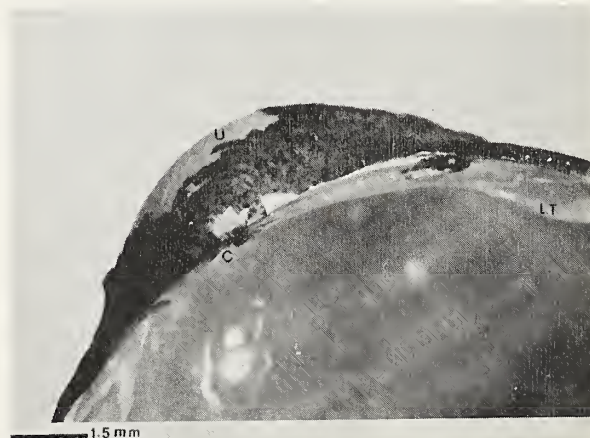


Fig. 1A. Internal view of portion of left shell valve of *Corbicula*. C, cardinal tooth; LT, lateral tooth; u, umbo; L, ligament.



1B. Internal view of portion of shell valve of sphaeriid clam, *Sphaerium*. c, cardinal tooth; LT, lateral tooth; U, umbo.

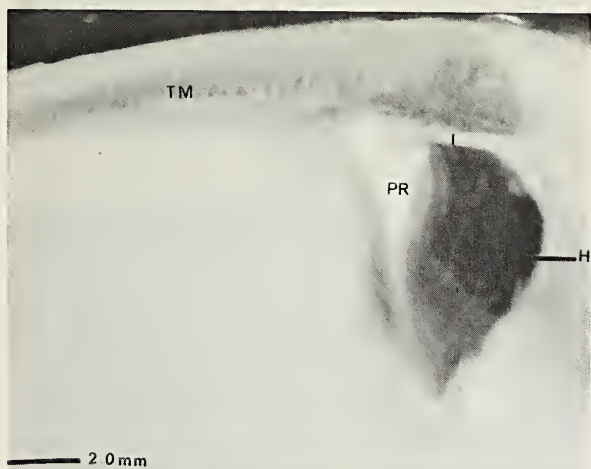


Fig. 2. Surface view of left posterior dorsal portion of *Corbicula*. TM "toothmarks" indicating region where mantle was gripped by serrated lateral teeth; H, cavity originally occupied by posterior adductor muscle; I, intestine; PR, left posterior pedal retractor muscle.

clearly visible against the posterior pedal retractor muscles.

Adductor muscles of "pill" clams also seem anatomically independent of the mantle. In contrast, in river mussels, mantle tissue adheres closely to the distal lateral edges of the adductor muscles.

There is fusion of the mantle margins in front of the branchial siphon. This resembles structure of the pedal gape in "pill" clams, again contrasting with the river mussels which show no mantle fusion anterior to the branchial siphon.

There is a prominent modification of the posterior end of the mantle, which is similar to that of the "pill" clams, but strikingly different from that of the mussels. The inner fold of the mantle edge is greatly thickened with muscle tissue, and is fused dorsally and ventrally to form a deep pocket. The thickened part of the mantle can be seen laterally, as it extends from a point on a level with and distal to the posterior adductor muscle, and widens under the latter muscle, and then narrows near the pedal gape.

Within the siphonal pocket, the inner fold of the mantle margin is extended and fused to form the anal and branchial siphons (Fig. 3). In living *Corbicula*, pigmented tubercles and tiny tentacles

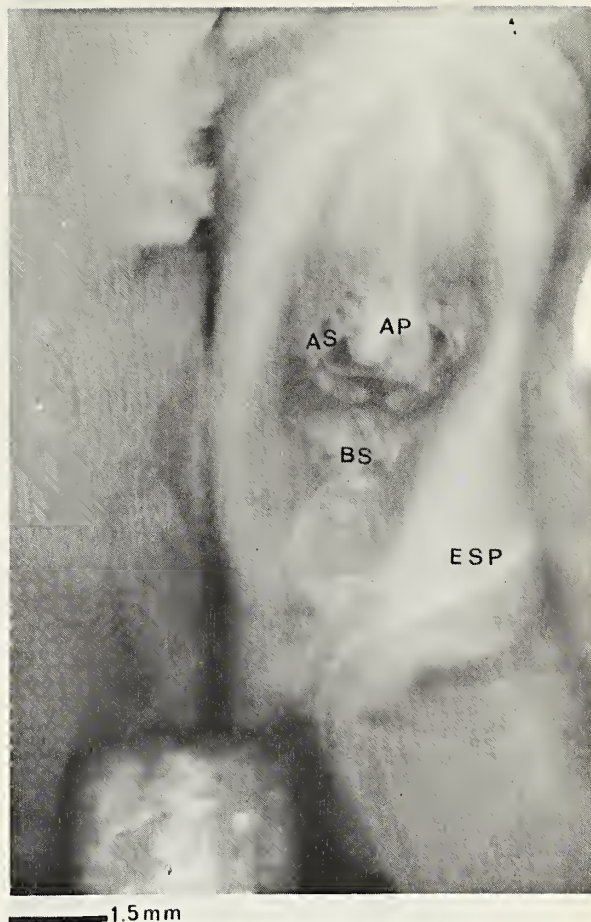


Fig. 3. External view of siphons of *Corbicula*, located within siphonal pocket. AS, anal siphon; AP, anal papilla; BS, branchial siphon; ESP, right edge of siphonal pocket, held back to show siphons.

stud the opening into the branchial siphon. A mid-point of mantle edge fusion above and below the siphons is marked by a row of small papillae.

Anterior to the siphonal pockets, the mantle thins and the three folds of its edges are readily observed.

Microscopic anatomy of the siphonal pocket, siphons, and related tissues:

In the wall of the siphonal pocket, masses of muscle fibers are interspersed with small branches of the pallial nerve from the visceral ganglion. Some groups of nerve fibers are associated with clusters of cell bodies, and resemble accessory mantle ganglia. External epithelium of the siphons

and siphonal pocket is comprised of columnar cells, each with a small distinct nucleus, near the margins of internal apertures of the siphons.

Internal to the siphons and to the siphonal pocket, and within the membrane surrounding the posterior adductor muscle, the intestinal rectum opens onto a prominent anal papilla (Fig. 3).



Fig. 4. *Corbicula*, sagittal section through region of siphonal pocket. BC, branchial cavity; BrS, branchial shelf; M, muscle of siphonal pocket; N, nerve; SC, supra-branchial cavity.

Within the mantle cavity and between the siphons, a thin membrane ties the distal end of the branchial shelf to the muscular wall of the siphonal pocket, effectively separating the supra-branchial cavity and the cloacal region from the branchial chamber. (Fig. 4). Just above the supra-branchial chamber, a similar membranous shelf contains a pair of nerves which may be traced anteriorly. On the latter shelf one may follow a pair of nerves from where they innervate a distal patch of epi-

thelial cells to their origin from the visceral ganglion. The visceral ganglion itself sits within the membrane where it sends short processes to an adjoining small mass of modified cells, apparently the osphradium of *Corbicula* (Fig. 5).

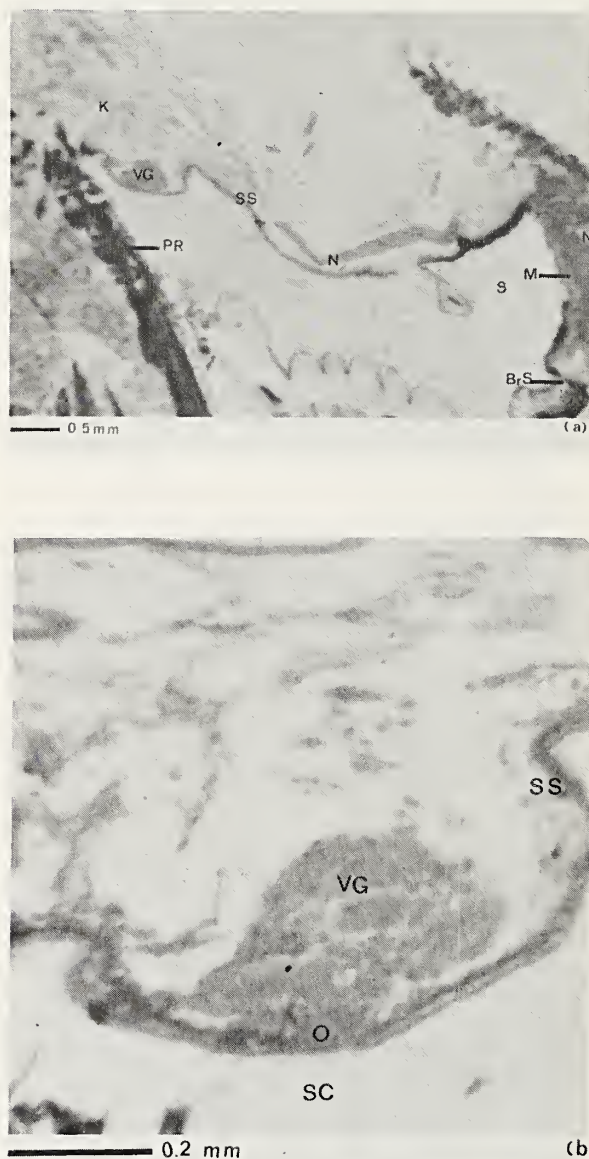


Fig. 5. *Corbicula*, sagittal section through region of visceral ganglion. (a) showing anatomical relationship of visceral ganglion to posterior pedal retractor muscle, supra-branchial shelf and siphonal muscle; (b) showing location of visceral ganglion within supra-branchial shelf; BrS, branchial shelf; K, kidney; M, muscle of siphonal pocket; N, nerve; O, osphradium; SC, supra-branchial cavity; SS, supra-branchial shelf; VG, visceral ganglion.

Where edges of the mantle form a smooth "hole" for passage of the posterior adductor muscle described above, one can demonstrate in microscopic frontal sections, that a pair of membranes form a prominent S-shaped suture, enclosing the posterior pedal retractor muscles, just where these muscles penetrate the visceral mass (Fig. 6). Ventrally these suture-forming membranes are continuous with tissue adjoining the gills.

Observations on the gross and microscopic anatomy of the gills:

The inner pair of gills is attached anteriorly so that dorsal openings into the water tubes are



Fig. 6. Frontal section of *Corbicula* through region of posterior pedal retractor muscles. S, s-shaped suture joining edges of membranous tissue which is contiguous dorsally and laterally with the mantle, and which is contiguous medially and ventrally with the branchial shelf. PR, posterior pedal retractor muscle tissue.

adjacent to gonoduct openings from the visceral mass. Microscopic sections of gravid *Corbicula* show embryos crowding the tubes of the inner gill. A comparison of outer and inner gills in cross-section, shows a contrast (Fig. 7). The inner gill appears to have slightly thicker vertical and horizontal connections and thus larger interlamellar spaces than does the outer gill. In whole mounts, both vertical chambers and horizontal openings in the inner gills are visible. Gravid gills show hundreds of embryos, the largest of which approximate the diameter of the horizontal gill openings. In preserved gravid specimens, embryos were especially numerous in posterior water tubes of the marsupial gills. Developing embryos could have made their way there from the gonoduct openings, into the suprabranchial chamber, thence into the anterior water tubes of each inner gill, and by way of the horizontal gill tubes to the posterior gill chambers. It seems highly likely that the embryos eventually move out of the posterior suprabranchial chamber, through the anal siphon, into the siphonal pocket, and thence to the exterior. In preserved specimens, embryos were found in all of the foregoing locations.

A note regarding the embryos:

Embryos retrieved from within the gills of *Corbicula* in this study were well developed. They

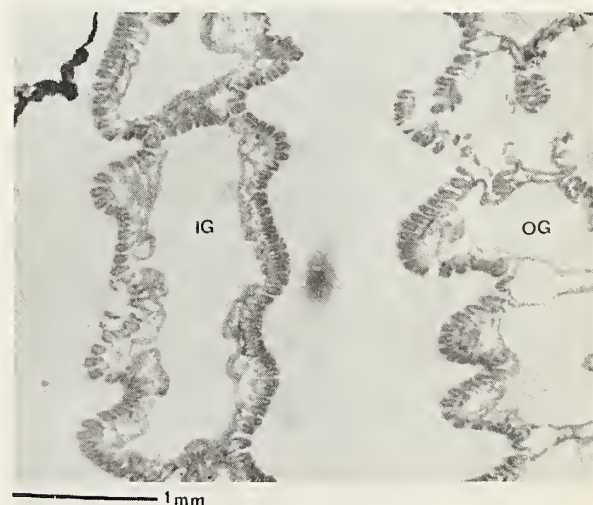


Fig. 7. Frontal section of *Corbicula*, through one pair of gills showing contrasting size of interlamellar structures. IG, interlamellar chamber in inner gill; OG, interlamellar chamber in outer gill.

showed adductor muscle tissue, development of the foot and visceral mass and gills. They had a distinct bivalved appearance, being oval in lateral view and compressed when viewed dorsally or ventrally. Embryos such as these probably are not destined for a prolonged planktonic existence.

DISCUSSION

No recent studies of the histology and functional morphology of the mantle complex of freshwater bivalves have been noted by this author. Older studies of *Anodonta* (Simpson, 1884) and studies of related structures and functions of course afford a useful background for understanding adductor muscle structure and function (Barnes, 1955, Hoyle, 1964), mantle fusion and function (Yonge, 1957), ligament organization and function (Trueman, 1954, Trueman, et al., 1966), mantle/shell/body relationships (Stasek, 1963), gill marsupia (LeFevre and Curtis, 1910; Coker et al., 1921; Heard, 1977), and innervation and neurobiology of the mantle complex (Rawitz, 1890; Dakin, 1928; Haas, 1935; Bullock and Horridge, 1965; Salanki, 1967).

From the above background and from results obtained in this study, it seems likely that a comparison of mantle structures affords a clue to the phenomenal spread of *Corbicula* in U.S. waterways at a time when indigenous river mussels are fast disappearing.

The mantle lobes of unionid mussels are mostly unfused. Their anal and branchial siphons are merely modified portions of left and right mantle lobe edges; the animal holds these in apposition to form functioning siphons. In the most highly evolved unionid group, the Lampsilinae, the mantle lobe edges are further modified into flaring, fish-like mantle flaps with a specialized spawning function (Kraemer, 1970).

In contrast, the deep, muscular protective siphonal pocket which encloses the tubular anal and branchial siphons of *Corbicula* is a conservative characteristic, not unlike that found in a number of marine intertidal species (Sellmer, 1967). Details of life history and functional morphology and behavior of *Corbicula* indicate an anatomy and physiology which appear to be far less highly evolved than that of autochthonous river mussels. The muscular siphonal pocket, along with production of numerous free-living pediveliger larvae and other "conservative" characteristics of the mantle/-

shell and mantle/gill complex of *Corbicula* may well account for what seem to be singularly accommodating capabilities of *Corbicula*.

To paraphrase Kirsch (1977, p. 176) who was writing about an adaptation-and-survival phenomenon in another group of animals, features of their behavior and functional morphology suggest that species of the bivalves genus, *Corbicula*, "represent an alternative but not inferior kind (of freshwater bivalve), valuable in understanding the course of (bivalve and bivalve habitat) evolution."

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THE ZOOGEOGRAPHY OF WEST AFRICAN LITTORINIDAE

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The coast of west Africa lies in at least three faunal provinces according to the information synthesized by Briggs (1974). Northern most is Lusitania which extends from the western side of the English channel south to Senegal and the Cape Verde Islands including the Mediterranean. South of this begins the tropical West African Province occupying the area between approximately 15 degrees N and 15 degrees S. The South Western Africa Province completes the coast terminating in the vicinity of Cape of Good Hope. Although not strictly west African faunally, the St. Helena-Ascension Province in the mid south Atlantic exhibits some west African elements and also shares species with the western Atlantic (Rosewater, 1975).

Although one might expect species of Littorinidae living on the west African coast to be endemic, this is the case only in a minority of the species. On the contrary, west African Littorinidae largely

derive from the west and north, a condition in contrast to that in the other world tropical faunal provinces where many endemic species occur. (See Rosewater, 1970, 1972; also tables 1 and 2).

DISTRIBUTION OF SPECIES

Two species occur also in the western Atlantic. *Littorina scabra angulifera* (Lamarck, 1822), which inhabits mangroves, is a subspecies of the pan-tropical *L. scabra scabra* (Linne, 1758). It ranges through the West African Province from Senegal to Angola. *Littorina meleagris* (Potiez and Michaud, 1838) which also occurs in the American tropics, apparently has become established in Ghana in the mid West African Province. Its habitat is similar in both hemispheres: algal mats in the low intertidal. It was suggested by Rosewater and Vermeij (1972) that *L. meleagris* may be a recent introduction to west Africa because of its limited

distribution there in the vicinity of shipping ports.

Two additional species which may be considered part of the west African fauna in the broad sense are migrants from elsewhere. *Littorina saxatilis* (Olivi, 1792) is reported sporadically in the Canary Islands, on the southern coast of Morocco, and, according to Kilburn (1972) in South Western Africa. It is usually thought of as illustrating a circumboreal Atlantic distribution, extending southward to Virginia in the west and to the Mediterranean in the east. The cited occurrence in South Africa could be interpreted as a bipolar distribution of *L. saxatilis* although it is possible that the species was introduced there on one or more occasions and has flourished in a suitable habitat. *Littorina neritoides* (Linné, 1758) is known from northern Europe and the Mediterranean. It also occurs in the eastern Atlantic islands such as the Azores, Madeira and Cape Verdes as an apparent extension of its distribution in the Lusitania Province.

Littorina punctata (Gmelin, 1791) and *L. cingulifera* Dunker, 1845, both live throughout the West African Province. *Littorina punctata*, acts like a eurythermic tropical species as its distribution also includes Lusitania where it is circum-Mediterranean and extends southward through the tropics at least to South Western Africa. *Littorina cingulifera* is an endemic species in tropical West Africa.

Littorina striata King and Broderip, 1832 could be considered an island species of southern Lusitania, were it not for one questionable occurrence on the mainland in Liberia in the northern tropical

West African Province. It is reported from the Azores, Madeira, and the Canary and Cape Verde Islands.

In the genus *Nodilittorina* there is one endemic tropical species, *N. granosa* (Philippi, 1848) occupying the West African Province from French Guinea to Nigeria. *Nodilittorina miliaris* is the only littorine inhabiting Fernando de Noronha, off Brazil, a part of the St. Helena-Ascension Faunal Province. The populations on Ascension and Fernando de Noronha appear fairly uniform, but the St. Helena population is sufficiently different to warrant recognition of the subspecies *N. miliaris helenae* (Smith, 1890).

DISCUSSION

As pointed out by Ekman (1953) the marine invertebrate fauna of West Africa is poorly known. Odhner (1923) showed that in the case of the mollusks it is a mixed fauna containing elements from several other areas, particularly from the north, and this certainly is the case with the Littorinidae. Odhner tabulated from the literature an impressive 63 per cent endemism in the littoral mollusks of tropical West Africa, with the largest additional component, 20.6 per cent, coming from Lusitania. Much lesser percentages were attributed to the western Atlantic and elsewhere. It is quite likely that a reconsideration of the species included by Odhner might change the percentage of endemism toward a lower figure. Odhner's per-

TABLE 1
DISTRIBUTION OF WEST AFRICAN LITTORINIDAE

	West Atlantic	Lusitanian	West African	S.W. African	Mid Atlantic Islands
<i>L. cingulifera</i>	—	—	X	—	—
<i>N. granosa</i>	—	—	X	—	—
<i>N. miliaris</i>	—	—	—	—	X
<i>N.m. helenae</i>	—	—	—	—	X
<i>L. striata</i>	—	X	X	—	—
<i>L. punctata</i>	—	X	X	X	—
<i>L. angulifera</i>	X	—	X	—	—
<i>L. meleagris</i>	X	—	X	—	—
<i>L. neritoides</i>	—	X	—	—	—
<i>L. saxatilis</i>	X	X	—	X	—

tages were based on a total mollusk fauna of 850 species. The more recent work of Nicklès (1950) contains only 459 species.

A number of inimical characteristics of the West African faunal province may account for the lack of development of strong endemicity in some mollusk groups, such as the Littorinidae (Ekman; Briggs, *ibid.*). Tropical West Africa barely stretches through 30 degrees of latitude, and is considerably narrower than the western Atlantic tropics which extend from above 30°N to nearly 20°S. This restriction of tropical conditions exists vertically as well as horizontally. Even where warm water is present near the surface it is replaced by colder water only 30-40 meters below the surface. While this deep cold water may have little influence on the adults of littoral animals it could affect their

planktonic larvae. It also could allow the introduction and maintenance of cooler water species from more temperate areas. In the case of the Littorinidae this thin layer of tropical water over colder water may be responsible for the phenomena of bipolarity, the presence of the same temperate species in both the North and South Temperate zones (see *L. saxatilis*) and eurythermy, where a species appears capable of living in several temperature zones (see *L. punctata*).

In addition to the cool temperature conditions, the West African tropical province has been characterized as a poor environment for tropical animals because the shore is overly sandy. It provides a poor substrate for reef corals which are, in turn, the habitat for many other tropical animals. There is said to be little protection from the surf. Also,

TABLE 2

LITTORINID ENDEMICITY IN TROPICAL FAUNAL ZONES

EAST PACIFIC 11	WEST ATLANTIC 10	EAST ATLANTIC 3	INDO-PACIFIC 27
<i>L. zebra</i>	<i>L. ziczac</i>	<i>L. cingulifera</i>	<i>L. undulata</i>
<i>L. aberrans</i>	<i>L. nebulosa</i>	<i>N. granosa</i>	<i>L. mauritiana</i>
<i>L. fasciata</i>	<i>L. tessellata</i>	<i>N. miliaris</i>	<i>L. kraussi</i>
<i>L. varians</i>	<i>L. lineolata</i>		<i>L. coccinea</i>
<i>L. modesta</i>	<i>L. angustior</i>		<i>L. praetermissa</i>
<i>L. paytensis</i>	<i>L. flava</i>		<i>L. pintado</i>
<i>L. aspera</i>	<i>L. mespillum</i>		<i>L. sundaica</i>
<i>L. penicillata</i>	<i>N. tuberculata</i>		<i>L. acutispira</i>
<i>L. porcata</i>	<i>T. muricatus</i>		<i>L. melanostoma</i>
<i>L. albicarinata</i>	<i>E. nodulosus</i>		<i>L. carinifera</i>
<i>N. galapagensis</i>			<i>L. unifasciata</i>
			<i>L. cincta</i>
			<i>N. pyramidalis</i>
			<i>N. natalensis</i>
			<i>N. australis</i>
			<i>N. nodosa</i>
			<i>N. millegrana</i>
			<i>N. subnodosa</i>
			<i>N. leucosticta</i>
			<i>N. cinerea</i>
			<i>N. picta</i>
			<i>T. coronatus</i>
			<i>T. grandinatus</i>
			<i>T. pagodus</i>
			<i>T. tectumpersicum</i>
			<i>T. rusticus</i>
			<i>E. cumingi</i>

severe changes of climate in West Africa during the Pleistocene may have interrupted or prevented speciation which was continuing elsewhere (Ekman; Briggs, *ibid.*). The total effect of inhospitable ecological and evolutionary conditions may explain, at least in part, the lack of much endemism in West African Littorinidae. The niches occupied in other world tropical provinces by endemic species have been filled in West Africa by invaders from the north and west having suitable ecological and physiological tolerances.

ACKNOWLEDGEMENTS

This consideration of the distribution of west African Littorinidae and of their comparative endemism, grew out of a study nearing completion on *Atlantide* Expedition collections of the family. Thanks are due Dr. Jorgen Knudsen, Zoological Museum, Copenhagen, for making these collections available to me. It is anticipated that an "Atlantide Report" will be published in the near future in which the classification and distribution of the group in west Africa will be more fully discussed.

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TECTONIC CONTROL OF CRETACEOUS AND TERTIARY DIVERSIFICATION AND PROVINCIALITY OF BIVALVES

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The Cretaceous Period marked the beginning of an increase in diversity within the Class Bivalvia. The appearance and rapid expansion in numbers of the eulamellibranch suspension feeders and the tellinacean deposit feeders are mainly responsible for this Cretaceous diversification. Eleven of the forty extant superfamilies of bivalves had their origin in the Cretaceous and Tertiary Tethys Sea.

The marine benthos is divided into epifauna and infauna corresponding to the respective inhabitants of hard or soft substrates. Yonge (1956) stated that apart from temperature, food and nature of the substrate are the major factors influencing

distribution. Nutrient supplies are in the form of suspended matter, detrital deposits and live or dead animals. Feeding habits are related to anatomical characters. Newell (1965) listed the anatomical criteria for all extant superfamilies of bivalves. Assuming that anatomical characteristics of Recent molluscs have persisted through time in the same taxonomic groups, it follows that the potential for a rapid anatomical diversification was present before the Cretaceous. This suggests that the general pre-Cretaceous ecological setting was not suitable for the eulamellibranch diversification.

Calculations from Moore (1969) show that 536

Table 1.

Geological Distribution of Genera and Subgenera
of Superfamilies of Cretaceous or Cenozoic origin*

Superfamily	Cret.	Paleo.	Eoc.	Olig.	Mio.	Plio.	Pleist.	Rec.
Chamacea	1	0	1	1	1	0	0	2
Leptonacea	1	4	23	2	16	8	0	68
Chlamydoconchacea	0	0	0	0	0	0	0	1
Tridacnacea	1	0	4	0	2	0	0	1
Maत्रacea	5	3	11	2	15	6	2	50
Solenacea	3	0	8	1	0	1	0	4
Dreissenacea	0	0	1	3	0	2	0	0
Gaimardiacea	0	0	0	0	1	0	3	1
Veberacea	28	5	46	39	37	13	8	52
Poromyacea	6	2	5	1	2	2	0	22
Clavagellacea	2	0	0	4	0	1	0	2
subtotals	47	14	99	53	74	33	13	203

TOTAL 536

*Taken from Moore, R.C. (ed.) 1969. Treatise on Invertebrate Paleontology, Part IV, Vols. 1 and 2, Mollusca 6, Bivalvia.

Table 2.

Number of Genera and Subgenera of Families
with Cretaceous and Cenozoic origins*

Family	No. of Taxa	Family	No. of Taxa	Family	No. of Taxa
Noetiidae	17	Psammobiidae	32	Raetomyidae	2
Glycymerididae	12	Icanotiidae	2	Spheniopsidae	2
Philobryidae	11	Scrobiculariidae	2	Teredinidae	29
Chondrodontidae	1	Semelidae	16	Monopleuridae	8
Trigonioididae	2	Solecurtidae	9	Caprotinidae	8
Ungulinidae	14	Bernardinidae	2	Caprinidae	23
Cyrenoididae	1	Euloxidae	2	Hippuritidae	12
Cyamiidae	9	Kelliellidae	8	Radiolitidae	40
Turtoniidae	1	Pollicidae	2	Pandoridae	6
Neoleptonidae	9	Trapeziidae	9	Cleidotheriidae	1
Condyllocardiidae	19	Glossidae	8	Lyonsiidae	9
Lahilliidae	2	Vesicomyidae	12	Margaritariidae	1
Lymnocardiidae	58	Myidae	13	Myochamidae	4
Tellinidae	101	Erodonidae	1	Periplomatidae	8
Donacidae	20	Pleurodesmatidae	1		
				TOTAL	549

*Taken from Moore, R.C. (ed.) 1969. Treatise on Invertebrate Paleontology, Part IV, Vols. 1 and 2, Mollusca 6, Bivalvia.

genera and subgenera of suspension feeding molluscs evolved within eleven superfamilies that had Cretaceous or Cenozoic origins (Table 1). Just as remarkably, 549 additional genera and subgenera of suspension feeding molluscs evolved within 44 families with Cretaceous origins that belong to superfamilies with Paleozoic or earlier Mesozoic origin (Table 2). The Cretaceous was also the beginning of a deposit feeding molluscan diversification that has continued to the present. There are 101 genera of protobranchs. Of these, 60 had Cretaceous or Cenozoic origins (Table 3). In addition there are the tellinids (Table 4) with 73 genera and subgenera, and the semelid deposit feeders of Cretaceous or later origin. The reason the tellinacean deposit feeders had such a competitive advantage in the Cretaceous is that the protobranchs had become reduced to only nine genera and subgenera in the Jurassic. As the Cretaceous seas spread the tellinaceans were able

to compete effectively for the newly opened carbonate areas and soon they showed greater diversities in the carbonate regimes of the extensive epicontinental seas. This niche partitioning was also satisfactory to the protobranchs. They also diversified, but after the Eocene they remained most common in the clastic regimes. The extensive shallow seas contained enough open area so that the older, as well as the more recently derived suspension feeding bivalves, flourished.

DISTRIBUTIONAL PARAMETERS

The zoogeographic distribution of an animal or community is determined by the individual's range of tolerances to ecological parameters and the means and barriers to dispersal. Classically, the most important ecological parameter determining the distribution of communities is temperature (Fischer, 1960). However, the distribution of car-

Table 3.
Geological and Geographical Distribution of
the Genera and Subgenera of Nuculacea and Nuculanacea*

	No. of New Taxa	Total No. Taxa	W.N. Am.	Carib.	N. Am.	Eur.	Medit.	W. Afr.	Indo Pac.	Pacific
Rec.	25	49	26	24	27	24	20	21	20	34
Pleist.	0	24	15	13	16	15	13	14	12	18
Plio.	1	24	15	13	16	15	14	14	12	18
Mio.	5	26	14	13	16	16	14	14	12	20
Olig.	6	22	13	13	15	16	13	13	13	18
Eoc.	10	21	13	13	18	15	13	13	12	16
Paleo.	4	11	5	6	8	9	8	6	6	9
Cret.	9	11	5	6	8	10	6	5	5	8
Jur.	6	9	2	2	3	9	5	2	4	4
Trias.	6	9	3	3	4	6	3	3	4	6
Perm.	4	7	1	1	2	2	1	1	2	5
Carb.	2	4	2	2	4	2	2	2	2	3
Dev.	5	10	3	3	5	8	3	3	3	3
Sil.	6	12	2	2	7	8	2	2	3	2
Ord.	12	12	2	2	6	10	2	2	2	2
Camb.	0	0								
Total	101									

*Taken from Moore, R.C. (ed.) 1969). Treatise on Invertebrate Paleontology, Part IV, Vols. 1 and 2, Mollusca 6, Bivalvia.

bonate, the 12°C ocean bottom water (Emiliani, 1961), and the distribution of tropical to warm-temperate plants and animals suggest a reduced latitudinal temperature gradient during the Cretaceous and early Tertiary. Nicol's (1972) report of higher percentages of deposit feeding bivalves (27 percent) in silty formations than in sandy areas (12 percent) or marls (10 percent) may, in fact, reflect the significance between clastic and carbonate substrates in distribution of benthic invertebrates. Additional calculations (Table 5) show that not only does type of substrate control the percentage of deposit feeders, but also what types of deposit feeders are present: protobranch or tellinacean. In silic-clastic muds protobranchs are more abundant than tellinaceans. Protobranchs and tellinaceans vary considerably but are nearly evenly distributed in silic-clastic sands. The Tellinaceans are most common in carbonate sediments. One possible explanation for this distribution is that the type of substrate may also reflect differences in types, amounts, and stability of nutrient supplies. Carbonate regimes are generally autochthonous in nature with sediments derived from within the depositional basin. This may also be true, to an extent, for nutrients. The amount of nutrients within the system would tend to be lower than for clastic regimes where rivers dumping sands and clays would contain large amounts of particulate and dissolved organic materials. The nutrient supply would, however, be continuous or

stable in contrast to the characteristic seasonal runoff of rivers. Valentine (1971) reviewed the influence of stability and amounts of nutrients to community adaptive strategy. Higher diversities should be expected in areas with stable, low resource supply. Ecological parameters alone do not control provinciality. Distributional mechanisms (currents), barriers (distance, land masses), types and duration of larval development, substrate type, and continuity and amount of habitable area (McArthur and Wilson, 1967) also influence endemism and provinciality. Through time, plate tectonic events control many of these factors. Active plate movements cause orogenic belts to develop, influencing climatic deterioration, sediment type and amount, and possibly nutrient regimes. Valentine and Moores (1972) discussed how plate tectonic processes affect the sizes, degree of emergence, and latitudinal patterns of continents. The shape and configuration of the continents influence and possibly control world climate, ocean currents, and distance between landmasses that contribute to faunal isolation.

DISCUSSION

The largest epicontinental seas, the warmest global temperatures, and a continuous substrate existed in the Cretaceous. Rapid diversification of eulamellibranch suspension and deposit feeders occurred as the shelf areas expanded over the

Table 4.

Geological and Geographical Distribution of Genera and Subgenera of Tellinidae*

	No. of New Taxa	Total No. Taxa	W.N. Am.	Carib.	N. Am.	Eur.	Medit.	W. Afr.	Indo Pac.	Pacific
Rec.	31	53	14	12	6	15	3	3	4	29
Pleist.	1	22	8	11	4	13	3	3	4	6
Plio.	5	25	8	11	5	13	3	3	3	8
Mio.	8	22	6	10	3	14	3	3	2	7
Olig.	6	13	2	6	3	11	2	3	2	6
Eoc.	8	11	2	3	2	10	2	1	3	2
Paleo.	1	3	1	2	1	3	2	1	1	1
U Cret.	11	12	3	1	8	4	3	1	2	1
L Cret.	2	2	0	0	2	2	2	0	0	0
Total	73									

*Taken from Moore, R.C. (ed.). 1969. Treatise on Invertebrate Paleontology, Part IV, Vols. 1 and 2, Mollusca 6, Bivalvia.

Table 5

Relationship of substrate to deposit feeding bivalves

<i>Silic-clastic muds</i>			<i>Silic-clastic sands</i>			<i>Carbonates</i>		
Recent Antarctic (Nicol, 1966)			Pliocene Jamaica, Bowden Beds (Woodring, 1925)			Recent Jamaica (Humfrey, 1975)		
total	30		total	168		total	246	
protobranchs	4	13%	protobranchs	11	6.5%	protobranchs	3	1%
tellinaceans	0	0%	tellinaceans	22	13%	tellinaceans	43	17%
Recent Greenland (Ockelmann, 1958)			Eocene, France, Sands of Aizy (Harris and Burrows, 1891)			Oligocene Fla, Tampa Ins. (Mansfield, 1937)		
total	55		total	274		total	142	
protobranchs	12	22%	protobranchs	5	2%	protobranchs	5	3%
tellinaceans	4	7%	tellinaceans	20	7%	tellinaceans	9	6%
Eocene Calif, Arroyo Hondo (Clark and Vokes, 1936)			Eocene, Calif. Domingue Fm. (Clark and Vokes, 1936)			Eocene France, Upper Calcaire Grossier (Harris and Burrows, 1891)		
total	15		total	51		total	526	
protobranchs	3	20%	protobranchs	3	6%	protobranchs	2	2%
tellinaceans	1	7%	tellinaceans	3	6%	tellinaceans	8	8%

continents, opening new and unoccupied niches. Many of these new taxa were very successful and became widespread rapidly. Dispersal was rapid because of great uniformity of climate and substrate, because distances between continents was reduced and because ocean currents were effective aids in larval dispersal (Figure 1).

During the Eocene (Figure 2) ocean circulation patterns began to approximate present conditions. Tectonic events opening of the North Atlantic-Arctic Oceans (Smith and Hallam, 1971), continued sea floor spreading (Pitman and Talwani, 1972), restriction of the Mediterranean seaway, shrinking epicontinental seas (Termier and Termier, 1952), climatic deterioration (Figure 3), changes in distribution of substrates and nutrient supplies, and resultant faunal isolation, resulted in increased provinciality and diversity (Tables 1-4). Initial increased provinciality, with respect to the Cretaceous, occurred in response to changes in sediment type distribution. Later increased provinciality and endemism was caused by faunal isolation.

By the end of the Miocene (Figure 4) present day circulation patterns were established with the exception of those areas of Central America and

Gibraltar. Further reduction of shelf areas and carbonate substrate, with the further increased temperature gradient (as suggested by decreasing bottomwater temperatures) and greater intercontinental distances, interacted with each other to increase endemism and provinciality. Provinciality probably approximated Recent conditions.

Recent bivalve distributions exhibit the greatest provinciality and endemism since the Cretaceous. The Recent closing of Central America, the restricted interchange of the Mediterranean, the greater latitudinal temperature gradient, and the greatest intercontinental distances since the start of sea-floor spreading, have resulted in maximum faunal isolation (Figure 5).

CONCLUSIONS

The Figures illustrate general changes in ocean circulation patterns, continental configurations, shelf area (global percent flooding), and sediment types through time. These changes are responsible for the present day distribution of marine molluscs. Present day diversity, endemism, and provinciality are explained in several steps: 1. initial diversification in the Cretaceous as epicontinental

seas expanded; 2. increased diversity and provinciality in the Eocene because of faunal isolation in response to changes in temperature gradient, substrate, and distances between faunas; 3. further diversification in the Miocene because of continued faunal isolation; and 4. recent diversification with the greatest endemism and provinciality because of the greatest faunal isolation and environmental diversity. The degree of faunal isolation and environmental diversity are related to plate tectonic events.

The distribution of deposit feeding molluscs is dependent upon the type of substrate. Historically, many of the oldest groups have been displaced in the tropics (in areas of carbonate substrate) by later derived groups; however, this displacement has not been complete.

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Fig. 1. Cretaceous Reconstruction of Paleocurrents, Epicontinental Seas, Continental Configurations, and Sediment Type Distributions. Shaded areas represent land masses; $\bullet$, $\circ$, and $\square$ arrows indicate current directions; and sediment types are indicated; C for carbonates, and S for siliciclastics (after Gordon, 1973; Termier and Termier, 1952; and Pitman and Talwani, 1972).

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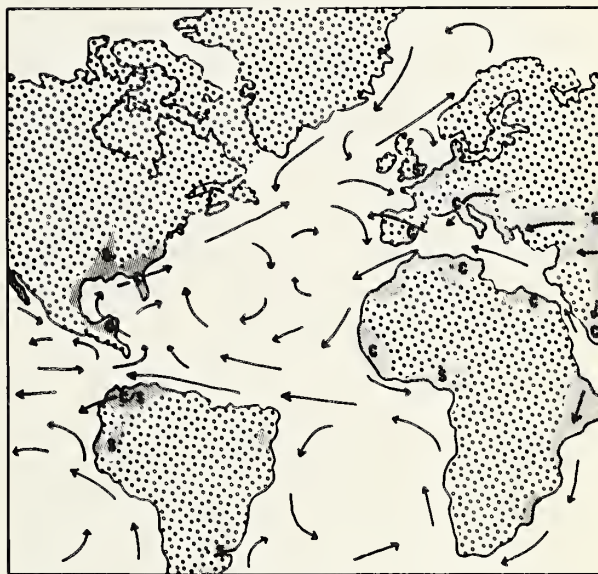


Fig. 2. Eocene Reconstruction of paleocurrents, Epicontinental Seas, Continental Configurations, and Sediment Type Distributions.

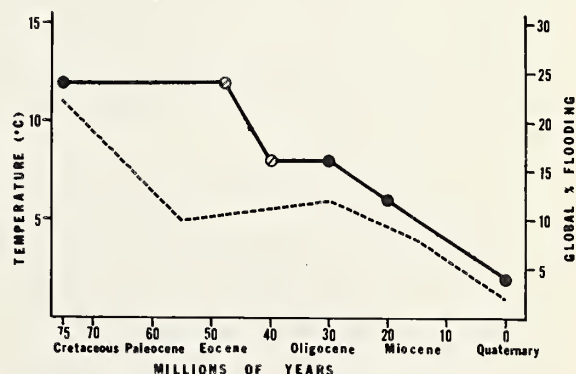


Fig. 3. Comparison of Paleotemperatures and Global % Flooding with Time. — Paleotemperature curve, ---- Global % Flooding curve (after Emiliani, 1961 ($\bullet$) and Savin et al, 1975 ($\circ$), and Termier and Termier, 1952).

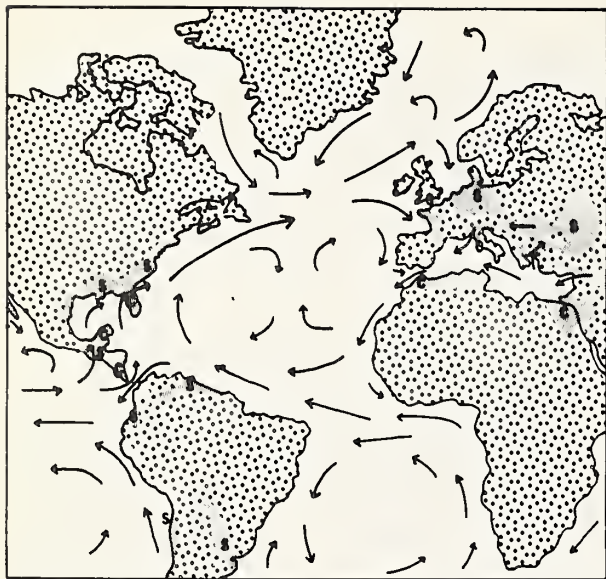


Fig. 4. Miocene Reconstruction of Paleocurrents, Epicontinental Seas, Continental Configurations, and Sediment Type Distributions.

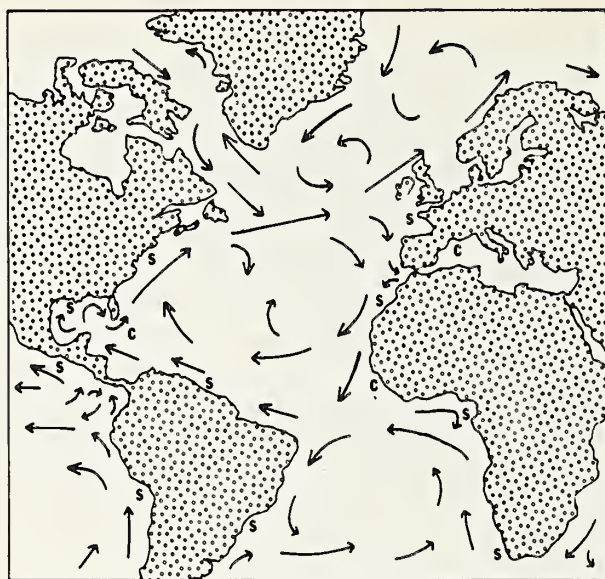


Fig. 5. Recent Configuration of Ocean Currents, Continents, and Sediment Distributions (Ocean Currents after Sverdrup, et al, 1947).

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THE WESTERN ATLANTIC DIMYIDAE

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The Dimyidae are small oyster-like bivalves that live only in the open sea. They differ from oysters, however, since they don't congregate in large numbers and they have paired adductor muscles. The genus *Dimya* was first described as a Paris Basin fossil by Rouault (1850). Later, a second genus, *Dimyodon*, was described by Munier-Chalmas (in Fischer, 1886). That same year, the first living species of *Dimya* was described by Dall (1886) from material collected by the "Blake" in the western Atlantic. Nine more Recent species, all from the Pacific, were described during the next 60 years.

There was a gap from 1944 to 1970 and then three papers concerning the family were published in rapid succession. (Moore 1970, Habe 1971, Bayer 1971). Moore described a new genus and species, Habe described a new *Dimya* and synonymized another, and Bayer described a *Dimya* and a new genus and species. So there are now thirteen Recent species in the family in three genera. Four of these species in three genera are found in the western Atlantic. They are as follows: *Dimya argentea* Dall, 1886; *Dimya tigrina*, Bayer, 1971; *Dimyella starcki* Moore, 1970; *Basilomya goreau* Bayer, 1971.

This paper will give a brief description with notes on the geographical and vertical distribution of each species.

Dimya Rouault, 1850

Type species, *Dimya deshayesiana* Rouault, 1850.

Shell small, thin, attached by the right valve. Resilium located in a small triangular pit, anterior muscle scar single, close to edge of shell, posterior double; this scar located between the center and the posterior edge of the shell. Pallial line usually marked with small denticles.

Dimya argentea Dall, 1886

Dimya argentea Dall, 1886, 228-233, pl. 4, figs. 5a, 5b

Shell white, silvery outside, opaque porcellanous

white inside, and almost always somewhat irregular in shape. Shell attached by the right valve which is deeper and larger than the free valve. Outline irregularly ovate, broader behind, with a short straight hinge line. The resilium is embedded in a subtriangular pit. Interior with an impressed area bounded by the pallial line, this area slightly raised. Posterior adductor muscle scar double, the anterior single, elongate oval and closer to the hinge line. Shell margin sharp, simple, and very thin—height up to 16 mm.

Dall, (1889), gave the range as Hatteras and Barbados. He also gave St. Vincent, St. Croix, and the Grenadines as localities. The species seems to have been almost ignored by everyone until Bayer (1971) published additional records. *Dimya argentea* was taken by the "Gerda" in the Northwest Providence Channel, along the western edge of Grand Bahama Bank, and in Santaren Channel a little north of Cuba. The "Pillsbury" collected additional specimens all along the Lesser Antilles and off La Tortuga, Venezuela. The range in depth was increased to 65-576 m.

Two of the additional records are here reported from the Gulf of Mexico, a new area for the species. June 1962, about 27° 25' N., 84° 40' W., depth 365-487 m, one right, one left valve. May 1963, about 27° 10' N., 84° 50' W., depth 335 m, one complete specimen, two right valves, one left valve. Gerda station 889, 20° 55' N., 86° 28' W., Arrow-smith Bank, depth, 110-220 m., one left valve.

Dimya tigrina Bayer, 1971

Dimya tigrina Bayer, 1971, 223-225, figs. 69, 71A.

This is a small species solidly attached to the substrate. Hinge line straight and long. There is a thin external ligament; a deep ovate pit accommodates the internal ligament, shape somewhat irregular and with thin concentric lamellae. There is little iridescence. Color pattern cream to pale brown with irregular radiating streaks of reddish brown, strongest on the shell margin. Length—holotype measured 9.4 mm.

Apparently only one complete specimen was

taken off Punta Piedras, Colombia, 9° 45.1' N., 76° 09.1' W., in 75-79 m. It was with some surprise that additional specimens were identified from the upper Gulf of Mexico, some 2600 km to the north. These specimens are smaller, reaching only 5.0 mm compared to 9.4 mm for the holotype. It was thought that the Gulf specimens might belong to a different species, but compared with the holotype, the only consistent difference found was size. These specimens were collected during MAFLA cruise I, 1975, at stations 2644 and 2645 off the Florida-Alabama coast.

One specimen, a free valve, was collected at Station 2644, 29° 36' 12" N., 87° 23' 30" W., depth 70.7 m. Station 2645, at 29° 35' N., 87° 20' W., depth 107.3 m, had four attached, two free valves. These records increase the range of *Dimya tigrina* from northern South America to the continental shelf off Alabama-Florida. It is the second species of the family to be reported from the United States continental waters.

Dimiyella Moore, 1970

Type species, by original designation, *Dimiyella starcki* Moore, 1970.

Shell small, hinge straight, with a tooth at each end in the lower valve. Brood chamber formed at the distal margin of the upper valve.

Dimiyella starcki Moore, 1970

Dimiyella starcki Moore, 1970, 138-139, 1 pl.

Small shell attached by the right valve. The free valve usually a little convex. Shape irregular; about ten poorly defined radiating ribs present on the upper valve but often indistinct.

Hinge long and straight, bearing a fairly stout conical tooth at each outer end of the lower valve. These teeth appear to rise from under the hinge plate. There are small sockets in the upper valve opposite the hinge teeth. Small triangular resilium located under the center of the hinge plate. Inner margin of the upper valve marked by a line of denticles. Its counterpart in the lower valve is marked with a series of small pits. Mature specimens partition off a brood chamber along the distal edge of the upper valve.

Length, about 3.0 mm (for attached valve, upper valve smaller).

Upper valves of *D. starcki* were found in

sediment samples from Cozumel, Mexico in 1971, and again more recently in 1976. Additional records include: Five upper valves from a sediment sample from 27.4 m, Roatan Island, Honduras; Eight upper valves from a sediment sample 1.6 km east of Wax Cut, Andros, Bahamas, depth, 3 m.

The Roatan Island sample was collected by Dr. Donald Marszalek, July 1974, at the foot of a vertical wall. Once the upper valves of *Dimiyella starcki* become detached, they become part of the sediment. They could have been living in shallow water near the vertical drop, then were carried over the edge by the action of waves and currents. Or they could have been living on the face of the wall itself. In either case they would have been collected below the area in which they had been living. The Andros Island specimens came from the edge of a patch reef some distance from deep water. This material was collected by myself, 28 August, 1971, on "Gerda" cruise G7124. The known depth range for *Dimiyella starcki* is now 2 to 27.4 m, but the lower figure is an artifact of collecting. This species appears to have a cryptic habit, but lives in very shallow water. No other species in the family lives in water this shallow.

Basilomya, Bayer, 1971

Type species by original designation, *Basilomya goreau* Bayer, 1971

Shell small, subcircular in outline, with a straight hinge line. Resilifer set in a strong tooth-like structure in the attached valve, with a blunt triangular tooth at each end of the hinge in the upper valve.

Basilomya goreau Bayer, 1971

Basilomya goreau Bayer, 1971, 227-229, figs. 70, 71, C-E.

Small shell attached, usually to the under surfaces of corals. Upper valve convex on the early part, concave near the margin. Attached valve cupped, and terminates growth with a frilly margin growing up and partly over the free valve. Hinge line straight. Resilifer a small pit tucked underneath a bilobed projection. A blunt triangular tooth appears at each end of the hinge in the upper valve with corresponding sockets in the lower valve. Inner boundary of the pallial impression marked by a series of round or ovate shallow pits; in the attached valve the upward curvature of the shell

begins at the pallial impression and thus is difficult to see.

Length of upper valve, 4.7 mm, height, 4.8 mm; length of attached valve, 7.1 mm, height 5.9 mm (holotype). This includes the marginal frill on the lower valve.

The type locality is Discovery Bay on the north coast of Jamaica, depth, 52 m. It has also been taken along the east coast of Andros Island, Bahamas, in 23-30 m.

SUMMARY

The vertical and geographical distribution of four species of Dimyidae in the Gulf of Mexico and Caribbean, with the addition of new records from the past several years, is reviewed. *Dimya argentea* has now been found in the eastern Gulf of Mexico and the western Caribbean. *Dimya tigrina* has had its range enormously increased from the Caribbean coast of Colombia to the northern Gulf. *Dimyella starcki* has now been collected off the coast of Honduras and on the east side of Andros Island, Bahamas. There is no additional information on the distribution of *Basilomya goreau*, although presumably, the species should be found in areas between Jamaica and Andros. There is virtually no additional information on the biology of any of the species. This is no surprise, however, as they all have a cryptic habit, and are also small, inconspicuous animals.

TAXONOMIC DIFFERENCES AMONG *TELLINA AGILIS*, *TELLINA TENELLA*, AND *TELLINA VERSICOLOR*

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The northern dwarf tellin clam, *Tellina agilis* Stimpson (1858), commonly inhabits shallow-water, sand-mud sediments along the eastern coast of North America from the Gulf of St. Lawrence to Cape Hatteras. North of Cape Cod, *T. agilis* is the only representative of its genus, but south of Cape Cod it is joined by *Tellina tenella* Verrill, 1873, and *Tellina versicolor* "Cozzens in Dekay", 1843 (Boss 1966). Conchological similarities among these three taxa make it difficult to identify specimens collected from Cape Cod to Cape Hatteras. This difficulty was encountered during ecological studies involving *T. agilis* (Gilbert 1973; Parker 1975) and was compounded when characteristics previously

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used to differentiate these taxa (Johnson 1932; Boss 1968) were found to be unreliable (see Discussion).

In the present study, quantitative relationships between shell-length and other conchological features were analyzed for each of the above taxa to seek effective means of assigning tellins collected from Cape Cod to Cape Hatteras to the appropriate taxon.

METHODS

Several lots of *T. agilis*, *T. tenella*, and *T. versicolor* were borrowed from the Division of Mollusks

at the National Museum of Natural History (USNM) and the Department of Malacology at the Academy of Natural Sciences in Philadelphia (ANSP). Specimens in the Peabody Museum of Yale University (YPM) and the Museum of Comparative Zoology at Harvard University (MCZ) were also examined. All specimens examined had been previously identified by Boss (1966, 1968) during preparation of his monograph on the Tellininae. Although there are relatively few specimens of *T. tenella* in museum collections, 28 shells of different lengths between 5-12 mm were available for measurement. Specimens of *T. agilis* (n=21) and *T. versicolor* (n=23) were selected to provide shell-lengths comparable to those of *T. tenella*; when several specimens of a desired length were available, selection was based on condition (i.e., not chipped or cracked).

All measurements were made on the right valve of each specimen. Length and height (Fig. 1) were measured with calipers (± 0.1 mm), the distance from the pallial line to the anterior muscle scar (hereafter referred to as PL-AM) was determined (± 0.01 mm) with an eyepiece micrometer at 4X magnification, and the shell-mass (± 0.01 mg) was weighed on an analytical balance. Quantitative analyses were made of (1) length vs PL-AM, (2) length vs mass, and (3) length vs height, by means of Bartlett's three-group method for Model II regression (Sokal and Rohlf, 1969). Photomacrophs of specimens were taken with a 35-mm camera and bellows to illustrate traits of interest.

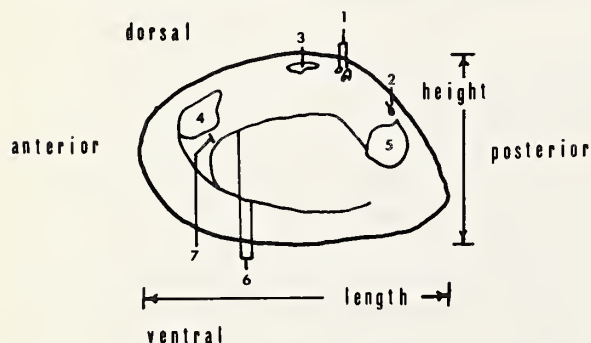


Fig. 1. Diagram showing characteristics of the interior surface (right valve) of a tellin shell. 1 = two cardinal teeth, 2 = posterior lateral tooth, 3 = anterior lateral tooth, 4 = anterior muscle scar, 5 = posterior muscle scar, 6 = pallial line, enclosing the pallial sinus into which siphons are retracted, and 7 = distance from pallial line to anterior muscle scar, PL-AM.

RESULTS

Relationships between shell-length and PL-AM for each of the three tellins are shown in Figure 2. Equations for the lines are in the form of $\hat{Y} = a + bX$, in which $\hat{Y}$ = the predicted value of Y (PL-AM, in this case), a = the value of the intercept on the Y-axis, b = the slope of the line, and X = any given shell-length.

$$T. tenella \quad \hat{Y} = -0.104 + 0.093X \\ \text{(PL-AM approx. 8\% of length)}$$

$$T. agilis \quad \hat{Y} = -0.066 + 0.049X \\ \text{(PL-AM approx. 4\% of length)}$$

$$T. versicolor \quad \hat{Y} = 0.091 + 0.008X \\ \text{(PL-AM approx. 2\% of length)}$$

The 98% confidence-limits about the slope for *T. agilis* are 0.020-0.81, so slopes for *T. tenella* and *T. versicolor* are significantly different.

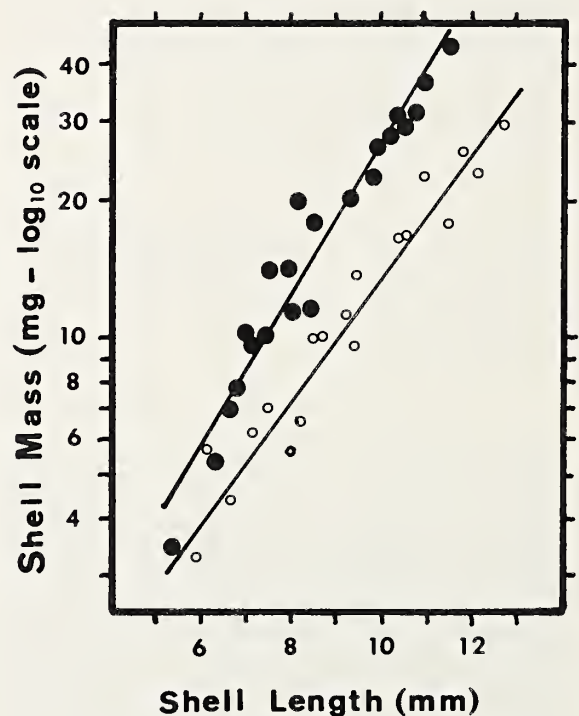


Fig. 2. Model II regression of PL-AM on shell-length for *T. tenella* (large, solid circles), *T. agilis* (open circles), and *T. versicolor* (small, solid circles; see text for equations).

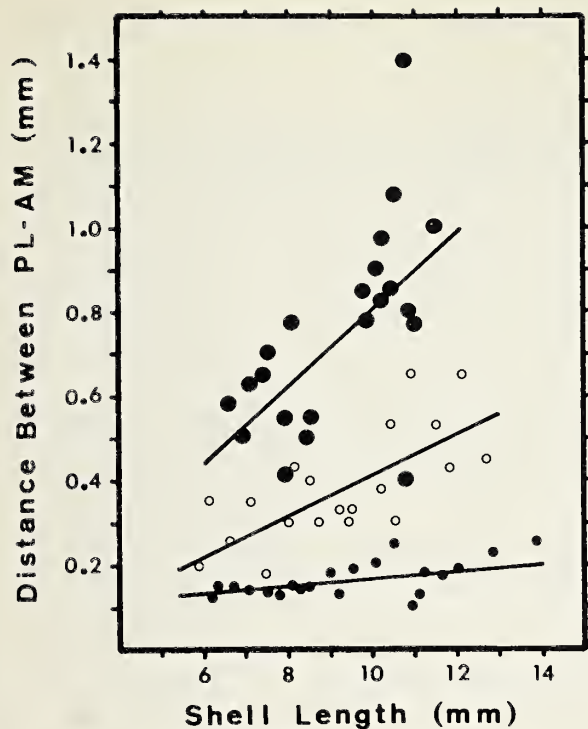


Fig. 2 Model II regression of PL-AM on shell-length for *T. tenella* (large, solid circles), *T. agilis* (open circles), and *T. versicolor* (small, solid circles; see text for equations).

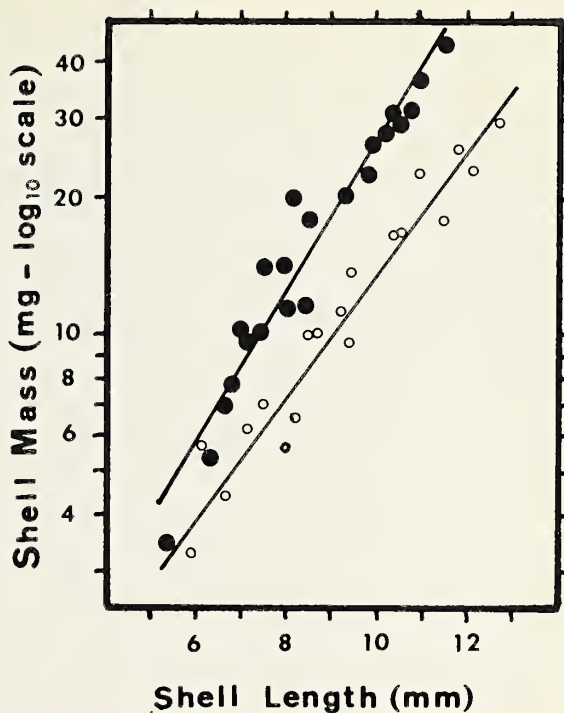


Fig. 3. Model II regression of shell-mass on shell-length for *T. tenella* (Large, solid circles) and *T. agilis* (open circles); see text for equations.

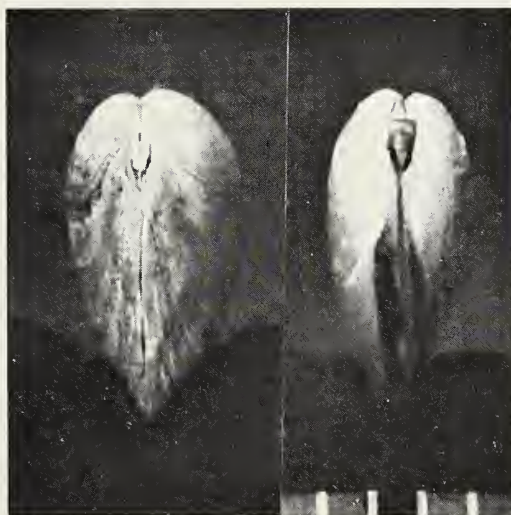


Fig. 6 View of posterior margin of (left) *T. tenella* (USNM 76973), with no flexure to the right, and (right) *T. agilis* (USNM 33728) in which valves meet after 'flexing' to the right of the midline; millimeter scales at bottom.

Relationships between shell-length and mass for *T. agilis* and *T. tenella* are shown in Figure 3. Linear equations for the three taxa are as follows:

$$T. tenella \quad \log \hat{Y} = -0.246 + 0.168X$$

$$T. agilis \quad \log \hat{Y} = -0.233 + 0.137X$$

$$T. versicolor \quad \log \hat{Y} = -0.246 + 0.134X$$

The 98% confidence limits of the slope for *T. agilis* have an upper limit of 0.165, so *T. tenella* differs significantly in this trait (but *T. agilis* and *T. versicolor* are very similar).

Linear relationships between shell-length and height had slopes that did not differ significantly. Equations are:

$$T. tenella \quad Y = 0.335 + 0.563X$$

$$T. agilis \quad Y = 0.281 + 0.561X$$

$$T. versicolor \quad Y = 0.177 + 0.539X$$

Raw data for the actual measurements are available from the author. Some photomicrographs are presented in Discussion.

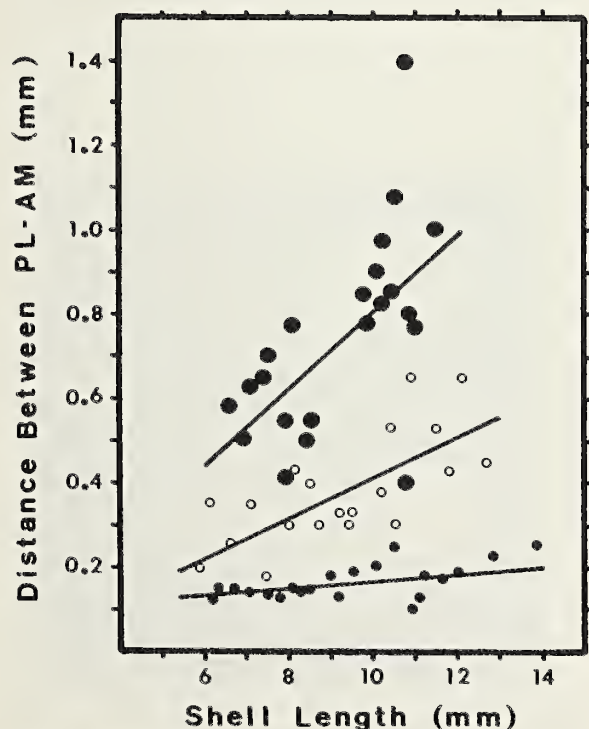


Fig. 3. Model II regression of shell-mass on shell-length for *T. tenella* (Large, solid circles) and *T. agilis* (open circles); see text for equations.

DISCUSSION AND CONCLUSIONS

The results provide guidelines for distinguishing *T. agilis* from the other two tellins (between Cape Cod and Cape Hatteras): (a) the PL-AM distance on the right valve of *T. agilis* is usually between 2.5-6% of shell-length, whereas it is nearly always less than 2.5% in *T. versicolor*, and (b) *T. tenella* differs from *T. agilis* by its greater PL-AM distance (usually more than 6% of shell length; see Fig. 2) and its much more massive shell (Fig. 3). These guidelines differ from those of Johnson (1932) and Boss (1968) in terms of the PL-AM distance, a trait which is evident in typical specimens of these three taxa (Fig. 4). Johnson reports that PL-AM is narrower in *T. tenella* than in *T. agilis*, but no measurements are cited. Boss (1968, p. 324) agrees with Johnson in the text of his monograph, but his diagrams (Boss, 1968: Plate 157, Figs. 1 and 2) agree with the present study in showing a narrower PL-AM for *T. agilis*. For this trait, *T. tenella* is particularly variable (Fig.

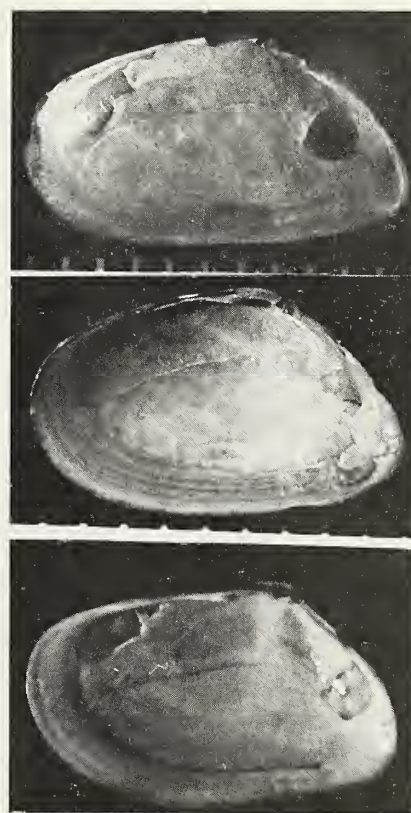


Fig. 4. Interior surface, right valve, of (top) *T. versicolor* (USNM 35781); (middle) *T. agilis* (ANSP 311371), and (bottom) *T. tenella* (USNM 34631); millimeter scales are shown for each specimen, since actual lengths differ.

2), which may account for the confusion described above. Additional confusion results from the guideline by Boss (1968, p. 301) that a PL-AM distance of 1 mm separates *T. agilis* and *T. versicolor*. As Fig. 2 shows, this distance is related to shell length, and only an exceptional specimen of *T. agilis* would have PL-AM greater than 1 mm. The lack of measurements for this trait prior to the present study probably reflects the need for a stereomicroscope with eyepiece micrometer to determine such small distances. By polishing the internal surface of a tellin shell with a moistened cotton swab, the pallial line can usually (but not always) be seen, particularly if the source of illumination is moved about until the etching is revealed by shadows.

If a specimen cannot be identified satisfactorily by the PL-AM guidelines, other specimens should be collected from the same population. By comparing the relationship between length and PL-AM for a group of specimens with those given in Fig. 2, an affinity between the unknowns and one of the three taxa should become apparent.

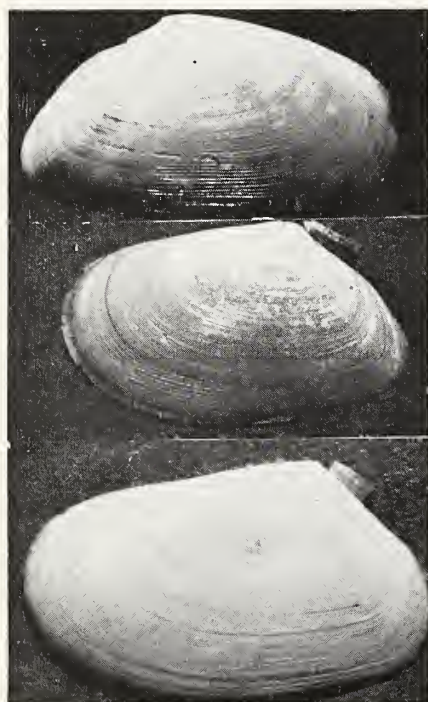


Fig. 5. The exterior surface of (top) *T. versicolor*, right valve actual length = 11.1 mm (USNM 35781), (middle) *T. agilis*, left valve actual length = 10.1 mm (Bourmes Pond, Falmouth, Cape Cod, coll. Oct. 1969) and (bottom) *T. tenella*, left valve actual length = 9.7 mm (ANSP 174604).

Additional specimens from populations of either *T. agilis* or *T. versicolor* should be readily obtainable, since their densities are usually over 100/m² and 10/m², respectively (Gilbert 1973; McNulty et al 1962). However, additional specimens of *T. tenella* might not be found. In thorough surveys of the type locality, Sumner et al (1913) found only one *T. tenella*, along with hundreds of *T. agilis* (= *T. tenera*), and Sanders (1958) found none. The length and mass (right valve) of a possible *T. tenella* specimen should be determined for comparison with the relationships shown in Fig. 3.

The present results show that the relationship of height to length for *T. agilis* and *T. tenella* is essentially the same (height is around 60% of length in both cases), so this characteristic will not differentiate between these two taxa as previously believed (Johnson 1932; Boss 1968, p. 310). The slightly lower proportions of *T. versicolor* (height = approx. 56% length) are not significantly different from the other two, but even the small difference predicted by the equations given in Results may help to identify a possible specimen of *T. versicolor*. Bartlett's three-group method for Model II regression, as used in this study, may be a useful tool for other taxonomic studies in which standard regression methods do not apply.

The nature of the concentric sculpture on the exterior of the shell (Fig. 5) has been considered to differentiate these three tellins (Gosner 1971,

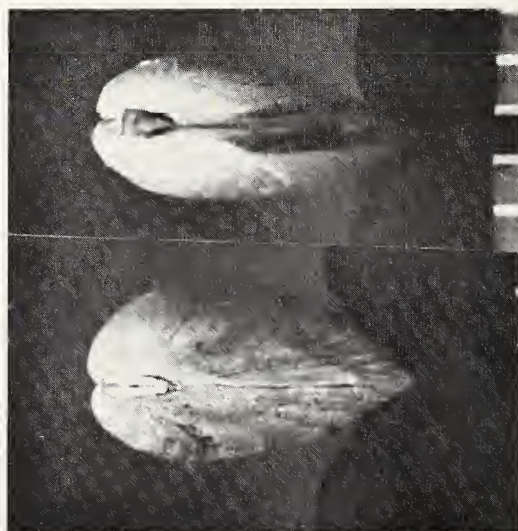


Fig. 6. View of posterior margin of (left) *T. tenella* (USNM 76973), with no flexure to the right, and (right) *T. agilis* (USNM 33728) in which valves meet after 'flexing' to the right of the midline; millimeter scales at bottom.

following Boss 1968). The sculpture of *T. tenella* is referred to as "raised concentric lirations", whereas it is considered to have "finely incised sulci" in both *T. agilis* and *T. versicolor* (Boss 1968, p. 301). The difficulty with these criteria is that both features co-occur, with raised lirations (ridges) separating incised sulci (grooves, scratches), or vice-versa. The sulci are described as "very closely spaced" for *T. agilis*, "closely spaced" for *T. tenella*, and "widely spaced" for *T. versicolor* (Boss 1968, pp. 309, 323, & 313, respectively). However, I have counted anywhere from 7-14 sulci per mm on shells of all these taxa, and groups of closely spaced and widely spaced sulci may be adjacent on the same shell (Fig. 5). Consequently, I consider this trait to be taxonomically unreliable. Another unreliable trait is shell coloration. Most shells of all three taxa are white but some of *T. versicolor* and *T. agilis* are yellow, pink, red, or violet and a few *T. tenella* are yellow-brown.

One feature that most tellin shells have is a posterior flexure to the right (Fig. 6). This is an adaptive trait of tellins that lie on their left valve when buried (Gilbert 1973; Holme 1961). With a flexure to the right, the long inhalent siphon (which feeds on the sediment surface) can be pulled in quickly to avoid predation (Gilbert and Suchow 1977); without a flexure, the siphon would have to be retracted over the sharp dorsal edge of the right valve, possibly severing it. Current-flow through the siphons is also more streamlined with a posterior flexure (Stanley 1970). For these reasons, it is peculiar that some larger specimens of *T. tenella* lack a flexure to the right (Fig. 6).

Results of this study provide quantitative guidelines for distinguishing among *T. agilis*, *T. tenella*, and *T. versicolor* by conchological differences. Studies of reproductive isolating mechanisms and/or of functional morphology of feeding (for the latter, see the paper by M.A. Gilbert in this *Bulletin*) are needed to verify that these taxa are separate biological species. One problem for such studies is the rarity of *T. tenella*, mentioned previously (also see Boss 1968, p. 324). Verrill based the taxon on a few specimens collected in the early 1870's, but he later suggested that it "may be only a variety of" *T. agilis* (Verrill 1882).

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MICROSCOPIC ANATOMY OF THE VISCERAL MASS OF *CORBICULA* (BIVALVIA: SPHAERIACEA)

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The rapid spread and establishment of the introduced Asian clam, *Corbicula*, through disturbed river systems in the United States from California to Florida stimulates inquiries into the fundamental biology of this bivalved opportunist. The present report reviews aspects of the morphology of the visceral mass and associated structures of *Corbicula*.

MATERIALS AND METHODS

Corbicula specimens used in histological preparations for this study were obtained at monthly intervals from a site on the Buffalo River in Searcy County, Arkansas. The animals were relaxed in 0.5% nembutal solution, placed in Bouin's fixative, and preserved in 70% ethanol. Dehydration in a graded series of tertiary butyl alcohols preceded embedding in 56-58°C Paraplast. Paraffin blocks were sectioned at 10 μ m in transverse, sagittal or frontal planes. Subsequently tissue slides were stained with an aniline blue variation of Mallory's triple stain (Schmitz, 1967). Approximately 6 animals each in the sizes ranges 2mm, 4mm, 8mm, and 20 mm were prepared in the foregoing manner.

OBSERVATIONS

Gross Anatomy of the Visceral Mass:

The visceral mass of *Corbicula* (Fig. 1) bears a general resemblance to that of other Sphaeriacea. It has the shape of a tall, corpulent triangle within the mantle lobes of the shell. It is attached dorsally to the mantle, and the mantle at its isthmus is in turn held in the complex tight grip of the strong, serrated anterior and posterior lateral teeth and prominent cardinal teeth.

On the dorsal, anterior face of the visceral mass a doubled pair of pedal muscles, and on the dorsal, posterior face, a larger pair of pedal muscles all make long, conspicuous insertions. The paired cerebral ganglia and their connecting, supra-oral commissure lie flat against the anterior pedal muscles (Fig. 2) where the latter insert on the visceral mass. Fused visceral ganglia nestle in a membrane which lies next to the insertion of the posterior pedal muscles on the visceral mass.

Just anterior to the cerebral ganglia, the anterior adductor muscle traverses a membrane-lined space, to insert under the sloping ridge of anterior lateral teeth on left and right valves of the shell. Im-

mediately posterior to the visceral ganglion, the large posterior adductor muscle traverses a similar membrane-lined space, making similar insertions on the shell valves under the posterior lateral teeth.

Distally, the visceral mass is attached to the thin, blade-shaped foot. Antero-laterally, two slender, pointed pairs of labial palps attach to the visceral mass on either side of the mouth. Dorso-laterally and just posterior to the palps, a pair of wide, long inner gills and a pair of narrower, shorter outer gills attach to the visceral mass (Fig. 1).

Microscopic Anatomy of the Visceral Mass:

External Wall of the Visceral Mass: The exposed anterior and posterior walls of the visceral mass are covered with a single layer of low cuboidal to low columnar epithelium, accompanied by a basement membrane and a thin muscular layer of short vertical and transverse fibers. Dorsally, where it abuts the mantle tissue, and ventrally where it attaches to the foot, boundaries of the visceral mass are clearly

demarked by a distinct, thin layer of connective tissue and some small muscle fibers.

Pedal Muscles: Within the epidermis, pedal muscle fibers form a pair of conspicuous tissue columns, anteriorly and posteriorly, for nearly the entire length of the visceral mass.

Gonadal tissue: Within the pedal muscle tissue of the visceral mass, gonadal tissue forms a conspicuous layer. Gonadal tissue is comprised of follicular canals which branch extensively in lateral and vertical directions. Sometimes dark finger-like extensions of gonadal tissue may be observed in whole preserved specimens of *Corbicula* on either side of a shallow dorsal medial groove in the visceral mass (Fig. 3). Follicular canals are located within a parenchymal stroma of sometimes loose, sometimes densely packed spherical cells. Most follicles in all specimens examined contained developing female gametes. The developing female gametes exhibit a wide size range (0.2-0.1 mm). They also vary greatly in shape. Many gametes appear to be budded off of the follicular membrane (Fig. 4) by a process similar to that of certain other mollusks (Raven, 1966), and further examined by Huebner and Anderson (1976). Follicular canals were most densely packed with female germ cells in *Corbicula* specimens collected in May. In contrast, specimens collected October-January showed fewer developing gametes.

In all specimens examined some testicular tissue was seen. Testicular tissue seldom seemed to comprise as much as 15% of the follicular material. In



Fig. 1. *Corbicula*. Drawing of preserved specimen, seen from the left side. Left valve and anterior portion of left mantle removed. Specimen collected from Buffalo River, Crawford County, Arkansas, July, 1975. AA, anterior adductor muscle; CT, cardinal tooth; FT, foot; IG, left inner gill; LP, labial palp; LT, serrated lateral tooth; M, left lobe of mantle; OG, left outer gill; PA, posterior adductor muscle; PR, posterior pedal retractor muscle; S, thickened region of mantle which forms the siphonal pocket; U, umbonal region. (Actual size of specimen, 3.5 cm.).

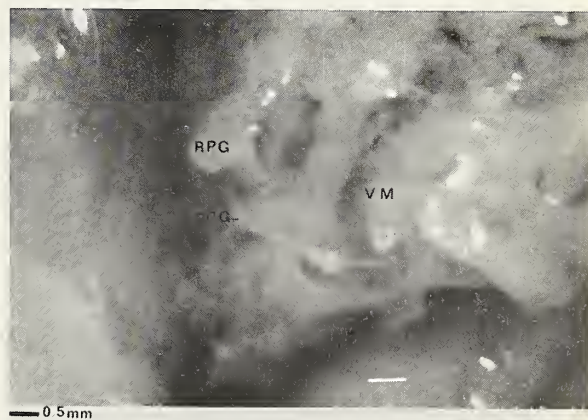


Fig. 2. Dissection of *Corbicula* (2 cm long) to show some antero-dorsal structures related to the visceral mass. Mantle and anterior adductor muscle have been removed. RCG, right cerebral ganglion; RPG, right pedal retractor muscle; VM, visceral mass.

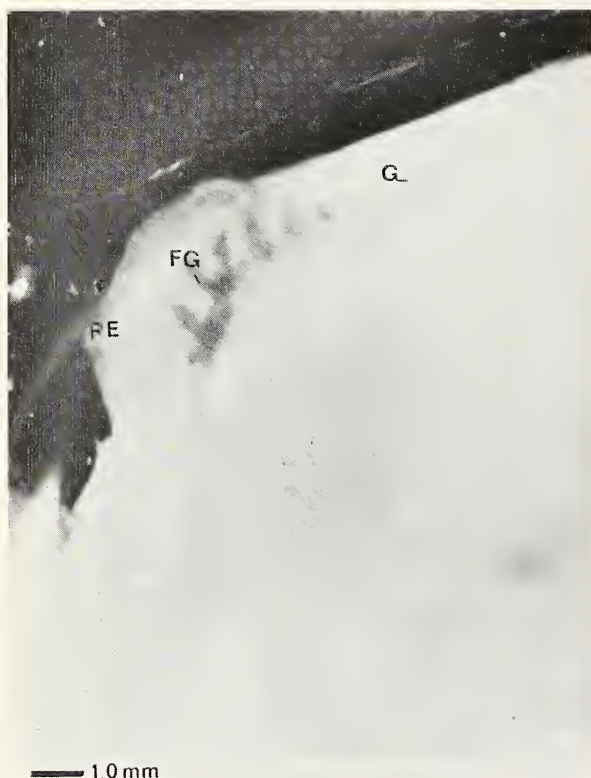


Fig. 3. Lateral view of dorso-anterior portion of visceral mass. G, dorsal medial groove in visceral mass. RE, right edge of visceral mass; FG, gonadal follicles, visible as dark finger-like canals through the membrane covering the visceral mass.

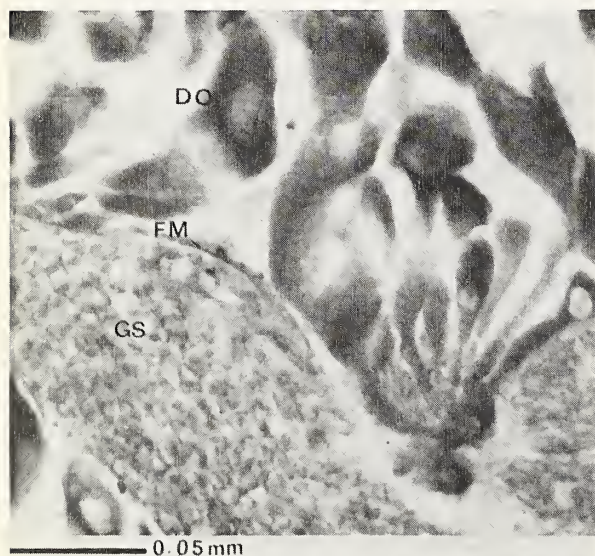


Fig. 4. Sagittal section of *Corbicula*, through the visceral mass, showing developing oocytes. Note that some seem actually to be budding off the follicular epithelium. DO, developing oocyte; FM, follicular membrane; GS, gonadal stroma.

specimens collected in October, seldom more than 3 or 4 small acini containing developing sperm cells were seen in a single 10 m sagittal section of the animal. In specimens collected in May, twelve or more spermatogenic acinar lobes could be seen in a similar section. Frequently such acini contained a number of spherical sperm clumps similar to those seen in Unionidae, (called "sperm morulae" by Yokely, 1972; see Fig. 5). In many specimens, but especially in those collected in May, it was not uncommon to find follicles in which developing and developed sperm cells and developing egg cells appeared to be commingled.

A puzzling observation was made of a pair of structures, situated within the gonadal stroma at the ventral posterior portion of the visceral mass. These occurred in specimens of various sizes collected throughout the study. Each of these appears to

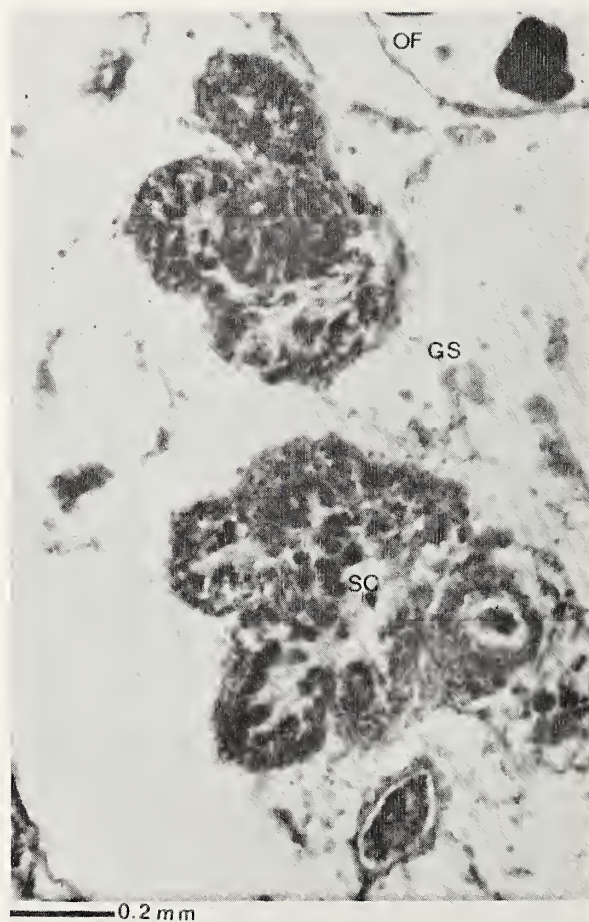


Fig. 5. Sagittal section of *Corbicula*, visceral mass, showing gonadal acini filled with spherical clumps of sperm. SC, sperm clump; OF, ovarian follicle; GS, gonadal stroma.

consist of a small spherical chamber, lined with low columnar epithelium. In several instances, the chamber greatly resembled a statocyst, even to the point of containing "statolith" material. Fine nerve branches were traced to the proximity of these chambers but innervation of the epithelial cells of the chamber wall was not seen. On the sides of these tiny chambers fairly large cell bodies resembling the soma of the neurons were frequently observed. In addition, these chambers were invariably surrounded by gonadal tissue containing developing sperm cells and occasionally, developing egg cells. (In some sections nearby gonadal follicles showed structures resembling embryos Fig. 6). A structure similar in appearance except for the hollow, statocyst-like chamber, was repeatedly observed in the gonadal stroma in the mid-dorsal regions of the visceral mass.

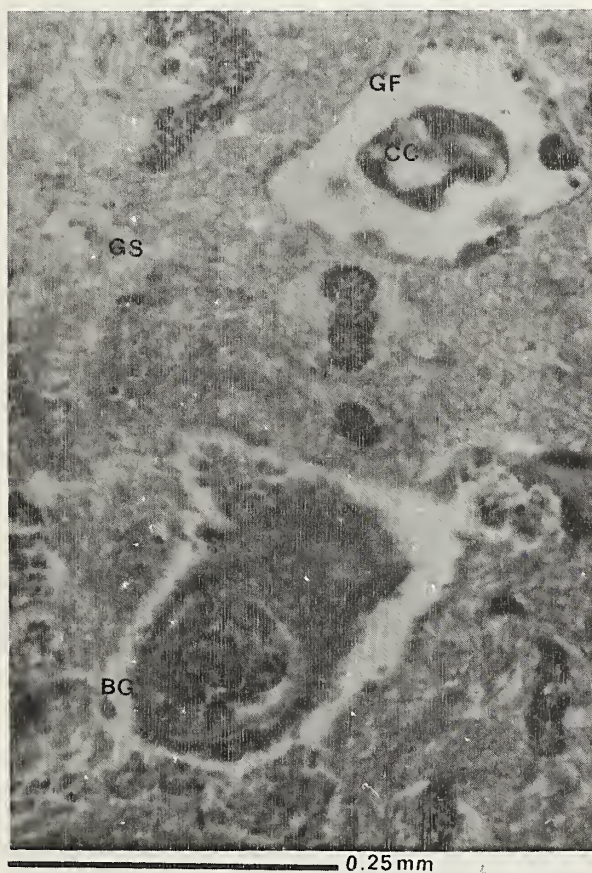


Fig. 6. Photomicrograph of posterior ventral section of visceral mass of *Corbicula*. PS, parenchymal stroma of gonadal tissue; GF, gonadal follicle; CC, cell cluster resembling an embryo; M, muscle; BG, structure associated with small spherical body described in text.

A pair of very short ducts, scarcely more than openings, were found to lead from gonadal follicular canals into the mantle cavity on each posterior, lateral aspect of the visceral mass, just dorsal to the attachment site of each inner gill to the visceral mass. The ducts are scarcely more than well-defined lips, covered inside and out with low columnar epithelium, which constitute openings into the mantle cavity (Fig. 7).

Digestive System Structures in the Visceral Mass:

Occupying most of the center of the dorsal half of the visceral mass, the digestive gland was determined to be comprised of a mass of compound tubular glands, branching and re-branching from paired ducts which connect them medially with the animal's stomach. In cross-section



Fig. 7. Frontal section of *Corbicula* in region of opening of follicular canal into epibranchial chamber. DO, ductile opening; EC, epibranchial chamber; F, follicle; K, kidney; G, gill; I, intestine; P, pericardial sac.

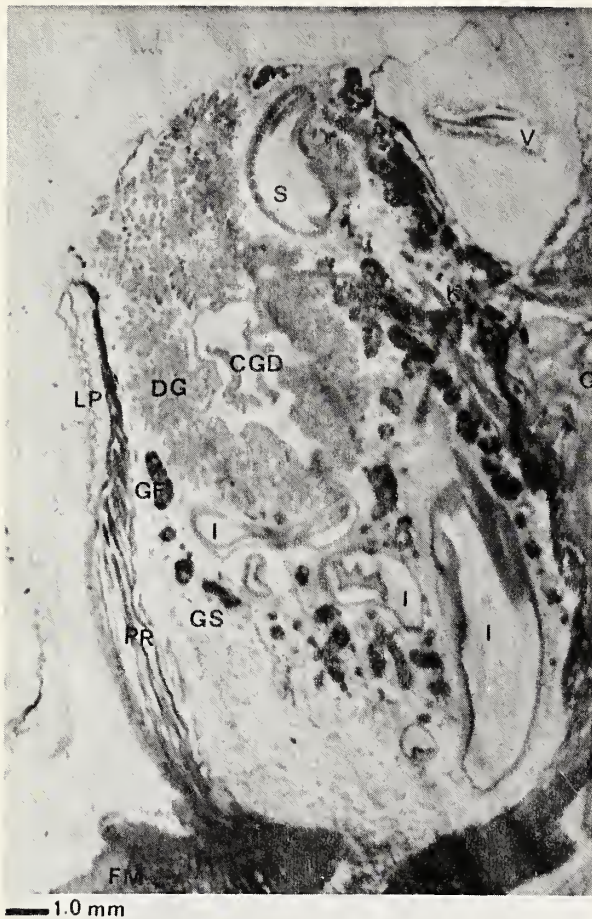


Fig. 8a. Sagittal section of *Corbicula*, region of visceral mass. Structures identified in visceral mass: S, stomach; GF, gonadal follicle; DG, digestive gland; CGD, confluence of digestive gland; I, intestine; GS, gonadal stroma; PR, anterior pedal retractor muscle. Peripheral structures identified: LP, labial palps; FM, foot muscle; V, ventricle of heart (showing segment of intestine); G, gill tissue.

the acini of these glands reveal a simple high cuboidal epithelium, surrounding a small lumen. Where the gonadal follicles described above tend to branch laterally and dorsally, the digestive gland acini branch horizontally, at right angles to the clam's body axis.

The digestive tract itself may be traced from the mouth which lies just under the cerebral commissure (Fig. 2). A ciliated epidermis extends between the pairs of labial palps and forms a hood-like shelf over the entrance to the mouth. Movement of food particles toward and into the mouth is doubtlessly facilitated by the position of the upward turned, ciliated flanges on the inner sur-



Fig. 8b. Sagittal section of *Corbicula*, region of stomach. S, stomach; CV, cerebro-visceral connective; GS, gonadal stroma; DG, digestive gland.

face of the outer palp and outer surface of the inner palp. The flanges are crowded more closely together as they approach the proximal ends of the palps, near the oral aperture. In sagittal section they offer the appearance shown in Fig. 8c.

The mouth gives way to a short tubular esophagus, which in turn leads into a large pouch-shaped stomach. In sagittal section, the stomach shows a complex mucosa of simple ciliated columnar epithelium, a basement membrane, and a submucosa containing a thin muscle layer. Frequently the mucosa will show a scalloped appearance, (Fig. 8); careful scrutiny suggests the "scallop" are due to contraction of short vertical muscle fibers in the stomach wall. Examination of many serial sections of *Corbicula* has not as yet revealed a clear understanding of the animal's crystalline style and style sac mechanism.

Posterior to the stomach the large digestive gland appears to crowd the intestinal loops laterally. These loops show a shallow typhlosole. In the ventral posterior sector of the visceral mass, the intestine become a large straight double vertical tube (Fig. 8a), its double appearance indicating the presence of a deep longitudinal fold in the gut wall, a major continuation of the typhlosole. Here the gut wall assumes a scalloped muscular appearance, reminiscent of the stomach wall. Extending vertically, the folded intestine finally exits from a point at the mid-dorsal, posterior surface of the epidermis of the visceral mass. From this point it traverses the heart ventricle within the pericardial sac, emerging from the pericardium posteriorly to curve around the dorsal posterior surface of the posterior adductor muscle and end in an anal papilla at the anal siphon.

Gut epithelium may be cuboidal, low columnar or high columnar, and is ciliated throughout. Long cilia especially crowd the mucosal surface in the lumen of the stomach, the major typhlosole region, and the rectum. While the looping intestine may penetrate the gonadal stroma of the visceral mass, much of the intestine occupies the center of the mass. Within the visceral mass, gonadal tissues are thus primarily peripheral to the digestive tract.



Fig. 8c. Sagittal section of *Corbicula*, showing characteristic appearance of inner surface of each labial palp. LP, labial palp; PR, pedal retractor muscle within visceral mass; GF, gonadal follicle; DG, digestive gland.

Musculature of the Visceral mass:

In addition to the pedal musculature described above, small but conspicuous bundles of transverse (Fig. 9) and longitudinal muscle fibers occur at frequent intervals throughout the gonadal stroma and less frequently among the digestive gland acini.

Nervous Tissues in the Visceral Mass:

In the anterior ventral section of the visceral mass the fused pedal ganglia form a conspicuous body (Fig. 9). Nerves branch from the pedal ganglia through the ventral portion of the visceral mass and down into the animal's foot. From the pedal ganglia a pair of long straight connectives extend vertically and pierce the dorsal anterior wall of the visceral mass to attach to the cerebral ganglia. In turn the cerebral ganglia send branching nerves to penetrate the anterior wall of the visceral mass and innervate the wall of the stomach, digestive glands, intestine, etc.

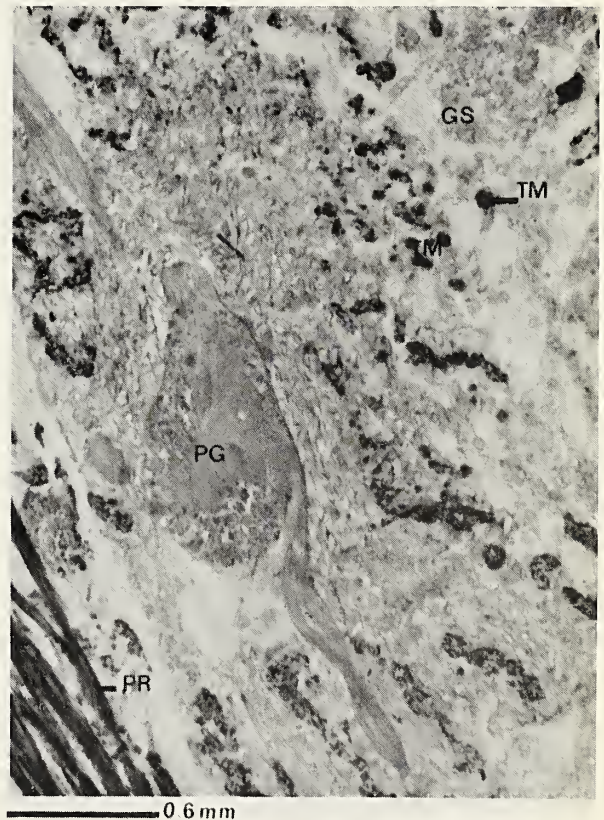


Fig. 9. Sagittal section of *Corbicula*, antero-ventral portion of visceral mass. PG, fused pedal ganglion; CP, cerebro-pedal connective; GS, gonadal stroma; PR, pedal retractor muscle; TM, small bundles of transverse muscle fibers.

On the dorsal posterior surface of the visceral mass, a pair of conspicuous connectives penetrate the mass on either side immediately lateral to the gonadal opening (Fig. 7) described above. These connectives then stretch like a pair of coarse cables straight through gonadal stroma and digestive glands, to emerge anteriorly from the visceral mass where they hook up with the cerebral ganglia just outside the mouth.

Visceral "pit":

A structure continually observed in this histological study of the visceral mass, was a deep branching pit which extends into the mass from a point on the anterior ventral surface where the visceral mass adjoins the foot. The pit's epithelial lining, continuous with the epidermis of the visceral mass, was followed through serial sections of a number of specimens to a point in the mid-ventral region of the mass, where the pit simply terminates.

Distal Border of the Visceral Mass, and Tissues of the Foot:

Beyond the distal margins of the visceral mass, the histological appearance of the tissues in the foot of *Corbicula* changes drastically. Muscle associated with the visceral mass is primarily in bundles — two large paired vertical bundles (anterior and posterior pedal retractor muscles) and many small transverse and longitudinal bundles (Fig. 9). Muscle tissue in the foot is also in three-dimensional array, but scarcely any bundles of fibers are visible. Instead, slender, single muscle fibers crowd the interior of the foot. Within the foot, the only other conspicuous tissue is comprised of numerous very slender nerves from the pedal ganglia which thread through the maze of foot muscle fibers.

Sinuses:

In the foot, not only are tissues differently arranged, but the sinuses, endothelium-lined spaces, are more numerous than in the visceral mass. Also, most of the foot sinuses are located within the center of the foot, from its dorsal to near its ventral margins. Sinuses in the visceral mass are associated primarily with the gut wall.

DISCUSSION AND CONCLUSIONS

No previous publications on the histological organization of the visceral mass of *Corbicula* have been found by this author. However, some

comment seems called for on similar nervous, digestive and reproductive components of the visceral mass of bivalved mollusks examined by other workers.

Cerebral ganglia, pedal ganglia and connectives were described *in situ* in this study. Bullock and Horridge (1965) comment that both topographic histology and pathways through the pedal ganglia of bivalves have scarcely been investigated since the work of Rawitz (1887, *Mytilus*) and Freidenfelt (1904, *Anodonta*).

In this paper it has been reported that the location of the cerebral ganglia is external to the visceral mass, in contrast with their position within the visceral mass in *Lampsilis* (Kraemer, 1970). Bullock and Horridge refer to the work of Drew (1908) which has been reviewed by this author as well — in which Drew attempted to establish experimental evidence of the functional relationship between cerebral and pedal ganglia. This writer feels Drew's experiments should be repeated.

The organization of the statocyst-like structures in the visceral mass of *Corbicula* resists comparison with statocysts of pelecypods such as *Lampsilis*. In the latter, a statocyst nerve emanates from each cerebral ganglion, and the nerve's fibers enter the connective tissue capsule of the statocyst, where they fray out among the epithelial cells of the organ's interior (Kraemer, 1969). Similar innervation of putative "statocysts" was not seen in this study of *Corbicula*.

Features of labial palps, mouth and stomach of *Corbicula* noted here conform to lamelibranch digestive anatomy described by others (Owen, 1966; Purchon, 1959). Details of style, style sac and typhlosole structure were not worked out for *Corbicula*. A consistent feature of *Corbicula* not seen in lamelibranch literature was the paired lateral loops of the intestine just ventral to the digestive glands.

The hermaphroditic condition in bivalves, reviewed by Fretter and Graham (1964) has been associated with an incubatory habit in a number of freshwater forms. In this study, *Corbicula* showed characteristics noted by Coe (1943) in functional hermaphrodites such as *Pecten irradians*. Both male and female gametes, though evidently formed in different parts of the gonads, seem to be shed through the same ducts (scarcely more than openings or gonopores in *Corbicula*). Coe noted this condition may be accompanied by self-fertilization. Fretter and Graham summarize evidence linking environmental factors to balanced and unbalanced

hermaphroditism and to self-fertilization.

Heard (1977) reported that male and female portions of sphaeriid gonads were less distinctly separated in small fingernail clams. In animals longer than 12 mm, the ovotestes were proportionately larger and the testicular portions "greatly predominated in size." In this histological study, even the largest *Corbicula* examined (20 mm) consistently showed a clear predominance of ovarian rather than testicular development.

From this study it is evident that while *Corbicula* is hermaphroditic, the amount of oogenic tissue present is invariably much more abundant than spermatogenic tissue. Oogenic follicles appear to be larger and much more crowded with oocytes in Arkansas specimens collected in May than at other times of the year. Similarly, testicular tissue in such specimens is more abundant and its follicular lumina frequently contain sperm balls. Additional and detailed data are reported in Lott (1977). These observations seem in accord with the finding in a recent study of the Arkansas River benthos (Kraemer, 1976) that young *Corbicula*, abundant in all samples, nonetheless declined in numbers from October to April.

Repeated observations of some intermingling of developing sperm and ova within gonadal tissue lead one to speculate that internal, self-fertilization may occur in this organism. In the course of the study, several observations were made of what appear to be embryos in early cleavage stages, within the gonadal tissue, (Fig. 6). Not enough evidence was available to confirm this observation.

Morton (1960) refers to lamellibranchs in which sperms and ova are formed in different regions of the same gonad, as functionally ambisexual, (as in the Pectinidae, Tridacnidae, *Sphaerium*, *Pisidium*, *Anodonta*). Fretter and Graham (1964) synonymize the term "functionally ambisexual" with simultaneous hermaphroditism to distinguish the latter condition from sequential production of male and female gametes.

Whatever terminology is eventually agreed upon, may depend on a clearer understanding of the reproductive physiology of bivalves. Here, however, we note that the hermaphroditic *Corbicula*, like the small sphaeriid "pill" clams, are reproductively independent not only of any reliance by the Unionidae, but may also be reproductively independent of each other. This capability, combined with several other characteristics

noted elsewhere (Kraemer, 1977) would seem to confer considerable selective advantage upon the introduced *Corbicula*.

ACKNOWLEDGEMENTS

Specimens of *Corbicula* used in gross anatomical study were from the Buffalo River, Arkansas, and from the Arkansas River in Arkansas. For comparative anatomical study, some preserved specimens collected in Egypt, as well as preserved specimens of *Sphaerium* and *Pisidium* collected in Livingston and Ore Counties, in Michigan, U.S.A. were kindly made available by the Mollusk Division of the Museum of Zoology, University of Michigan, Ann Arbor. Fig. 1 was drawn by Frances Waite.

Photomicrographs were made with a 35 mm Leica camera in conjunction with a Leitz Ortholux microscope equipped for bright-field transmitted light, and with a 35 mm Wild MKa 1 camera in conjunction with a Wild M5 stereomicroscope.

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ASPECTS OF FEEDING IN THREE SPECIES OF *TELLINA* (TELLINIDAE: BIVALVIA) FROM TUCKERTOWN BAY, BERMUDA

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INTRODUCTION

The study of the morphology of benthic invertebrates, especially molluscan bivalves, is a time-honored one (e.g., Kellogg, 1915; Graham, 1934; Yonge, 1949). Only recently, however, have investigators attempted to apply concepts of ecological theory to such species (Levinton, 1972, 1975). Studies focused on coexisting deposit-feeding species have demonstrated that particle size selection is one way competition is reduced, although the mechanisms may be only partially understood (Reid and Reid, 1969; Fenchel, et al., 1975; Muller, 1975; Hughes, 1975).

The morphology of the gills, palps and stomach of three deposit-feeding tellinids, *Tellina gouldii*, *T. candeana*, and *T. sybaritica*, that coexist in the small Tuckertown Bay, Bermuda, was examined.

Stomach and gut contents were measured to determine if differences in morphology resulted in differences in diet.

METHODS

After sieving the bivalves from Tuckertown Bay sediment, the animals were maintained in large bowls of the same sediment in water tables until dissection. The left valve of the individual specimen was removed and the animal placed in a syracuse dish of sea water. The anatomy was observed and a brief note made of the animals' reproductive status. Particles of carborundum (<20 μ) and sand from Tuckertown Bay were used to define ciliary currents. Palps were dissected away and preserved in an absolute alcohol and formalin (9:1) solution, embedded, sectioned (5 μ) and stained with hema-

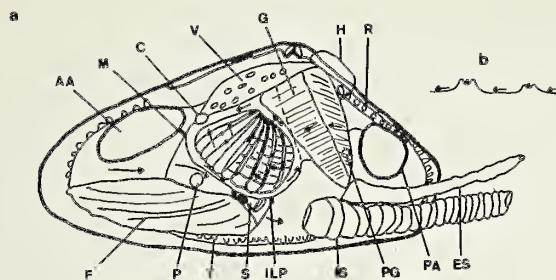
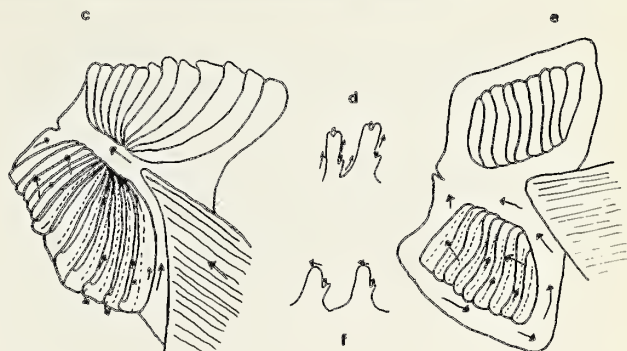


Figure 1a. Anatomy and ciliary currents in the mantle cavity of *Tellina sybaritica* viewed from the left. AA: anterior adductor muscle; C: cerebral ganglion; ES: exhalant siphon; F: foot; G: gill; H: heart; ILP: inner lobe of the labial palp—the dashed line indicates the location of the posterior margin of the outer lobe; IS: inhalant siphon; M: mouth; P: pedal ganglion; PA: posterior adductor muscle; PG: pallial ganglion; R: rectum; S: style sac, mid-gut and digestive diverticula; T: tentacles on mantle lobe; V:



visceral mass.

Figure 1b. Diagram of cross-section of the posterior palp ridges of *T. sybaritica* showing major ciliary currents.

Figure 1c. Diagram of the palp-gill junction of *T. candeana* showing major ciliary pathways.

Figure 1d. Diagram of a cross-section of the posterior palp ridges of *T. candeana* showing major ciliary currents.

Figures 1e, f. As in c and d, but for *T. gouldii*.

toxylin and eosin.

Dissection was made from the left side since it was least destructive to the stomach and gut (Reid and Reid, 1969). The contents of each were carefully removed, suspended in a weak sodium bisulfite solution to separate particles, and filtered out on 0.45 μ millipore filters for analysis using the methods described by Manheim, et al. (1970). Carborundum particles and Tuckertown Bay sand were again used to detect ciliary currents in the stomach. Data on the sediment particle size composition were kindly supplied to me by John Abraham and William Gilbert (Pestanca and Gilbert, 1977).

RESULTS

The major anatomical difference among the three species was the morphology of the palps. *Tellina sybaritica* is herein used as representative of the overall pattern and direction of the ciliary currents in the mantle cavity of the three species; the anatomy and currents of the palps and gills of the other two species are presented for comparison (Figure 1 a-f). In *T. gouldii*, the palp ridges are all much higher and rounder than the other two species. As in the other members of the Tellinidae (Gilbert, 1975, 1977; Reid and Reid, 1969), there

is also an aboral shelf on each ridge where cilia pass fine particles toward the oral groove, while large cilia on top of the ridges move particles orally.

In contrast with *T. gouldii*, *T. sybaritica* and *T. candeana* possess two types of palp ridges. On the oral third of the palp, the ridges of both species are simple and rounded. In *T. sybaritica*, the ridges of the posterior two-thirds are reduced to a simple, low groove bounded by parallel rows of ciliary cells. The cilia of the grooves pass particles dorsally, while the ciliated cells between the low ridges pass particles orally. In *T. candeana*, the posterior palp ridges are high, bearing both a prominent aboral shelf as in *T. gouldii*, and a ciliated groove on the top similar to that in *T. sybaritica*. The ciliation of these ridges is the most complex of all three species, as shown (Figure 1b). It should also be noted that the inner palps of both *T. candeana* and *T. sybaritica* are firmly attached along their posterior edge to the gill, whereas in *T. gouldii*, most of this edge hangs free, ventral to the gill.

The external appearance of the stomach of all three species is identical to that figured by Yonge (1949) for *Tellina tenuis*, except that the appendix (=posterodorsal caecum) in *T. gouldii* is exceptionally large and multi-lobed even when empty. The appendices of all three species were often full of

sediment, sometimes of fine particles (e.g. *T. candeana*) or of both fine and coarse particles (e.g. *T. gouldii*). This contrasts to previous observations (Yonge, 1949) of the presence of only coarse material.

The internal anatomy of the stomach, shown for *T. candeana* (figure 2b), is very similar in all three species to that figured for *T. crassa* (Graham, 1949) and *T. ala* (Dinamani, 1967). The rejectory groove (Reid and Reid, 1969), well-developed in *T. sybaritica* and *T. candeana*, was not observed in *T. gouldii*. Also the coiling of the major typhlosole in the left caeca may be present in *T. gouldii* and *T. sybaritica*, but was not observed. The typhlosole seems to end as a simple fold in these species.

The presence of a large appendix in the three species here produces the major difference in ciliary currents as compared to those species previously reported. The hood groove (=groove of the posterior sorting area of Reid and Reid, 1969) branches into the appendix in the species here discussed. The cilia in this branch move material out of the appendix, while the cilia on the stomach wall ventral to this opening move material either into the appendix or past its opening if it is closed.

The functioning of an intact stomach with an active, rotating style was observed in a specimen of *T. candeana*. The rotation speed of the style, 15 rpm, agreed well with that observed for *Modiolus* (13rpm; Nelson, 1918, quoted in Yonge, 1949).

Material of all sizes was drawn in from the esophagus and wrapped around the style. As the style rotated, the particles were carried around the gastric shield embayment; each time they passed the posterior sorting area (PSA), some were swept into the ciliary pathways there and were sorted. Large particles were passed back into the shield embayment by cilia on the outer portions of the PSA folds. Smaller particles fell into the grooves and were either swept into the caecal openings by the "rejectory" groove and the major typhlosole or were swept into the dorsal hood by the hood groove. Overall, the functioning of the intact stomach (Figure 2a) was as figured and described by Yonge (1949) for *Tellina tenuis*.

Figure 3a graphs the particle sizes of the stomach contents of one specimen each of the three species as the cumulative percent by weight and compares them to the particle size composition of the sediment. It is clear that all three species are actively selecting the finer components of the sediment, *T. sybaritica* and *T. candeana* to a greater degree than *T. gouldii*. Figure 3b shows the particle size composition of the fecal pellets of the same three specimens. Comparison with Figure 3a will show that the fecal pellets are finer in composition than the stomach contents in *T. gouldii* and *T. candeana*, but coarser in *T. sybaritica*.

Observation of the reproductive status of these species showed that in late March, 1976, the

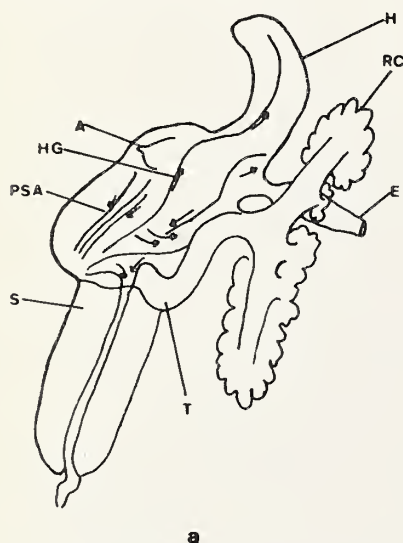


Figure 2a. Right exterior stomach of *Tellina candeana*.

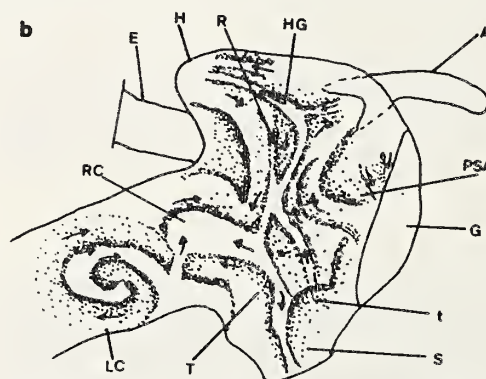


Figure 2b. Right interior of the stomach of *T. candeana*. A: appendix; E: esophagus; H: dorsal hood (normally folded along left side); HG: fold of the hood groove; PSA: folds of the posterior sorting area; RC: right caeca; S: style sac and mid-gut; T: major typhlosole; G: gastric shield; LC: left caeca; R: rejectory groove; t: minor typhlosole.

gonads of *T. gouldii* were in an advanced state of maturity, while those of the other two species were inactive. *Tellina candeana* may have recently spawned as one female contained a few residual eggs. *Tellina sybaritica* may spawn later since one male was in active gonadal growth.

DISCUSSION

The stomach contents indicate that all three species are mainly large sand grain feeders (particles larger than $60\ \mu = 70-90\%$ by weight; Figure 3a), but that *T. sybaritica* and *T. candeana* utilize the finer portion ($1-60\ \mu$) of the sediment to a much greater extent than *T. gouldii* (12 and 15% vs 4%). It is likely that the ciliated grooves on the palp ridges of the former two species enable the concentration of the fine particles. Since this portion of the sediment is much richer in microorganisms than the coarser fraction (Newell, 1965; Meadows and Anderson, 1968; Fenchel, 1972), this differential utilization alone may explain the coexistence of the three species. I also observed that the freshly opened stomachs of many *T. gouldii* were packed with large ($300+\ \mu$), live Foraminifera and spherical algae; *T. gouldii* may indeed specialize in large particles.

Observations on two other niche aspects provide further clues to the ability of these three species to coexist. First, *T. gouldii* is much more abundant than the other two in Tuckertown Bay. Second, the spawning seasons seem to be staggered: *T. candeana* before March, *T. gouldii* probably in late April, and *T. sybaritica* later in the summer. More work is necessary to clarify this aspect.

As noted above, there are differences in the particle size composition of the stomach contents and fecal pellets of the same individual. This is probably because the fecal pellets represent a condensed "history" of the activity of the stomach. Gut clearance time in other related species has been measured to be from 1-60 hours (e.g. Hughes, 1969; *Scrobicularia plana* from 8-60 hours; Hylleberg and Galluci, 1975; *Macoma nasuta* from 1-9 hours). It therefore follows that a sample of fecal pellets may represent any one of the phases of stomach and digestive diverticula activity of the previous several hours (Morton, 1970, 1973; Purchon, 1971). The stomach contents of an actively feeding animal are thus the only valid measure of what is actually ingested.

ACKNOWLEDGEMENTS

This study was carried out during a brief stay at the Bermuda Biological Station (BBS Contribution Number 726). I thank Dr. W.E. Sterrer, Director, for his very kind cooperation and Drs. William Gilbert and Harold Pestana for help in the field. Voucher specimens of the species discussed here have been deposited with the Delaware Museum of Natural History (nos. 121772-4).

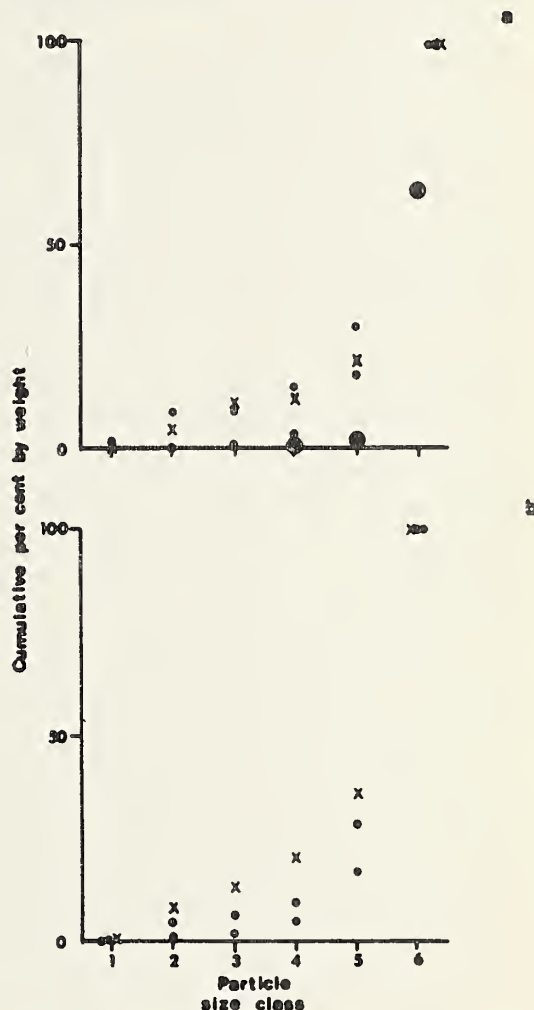


Figure 3a. Particle size composition of the stomach contents of a specimen of *Tellina gouldii* (●), *T. sybaritica* (○), and *T. candeana* (x) compared with the particle size composition of Tuckertown Bay sediment (●). Particle size classes: 1. 1-8 μ ; 2. 9-16 μ ; 3. 17-30 μ ; 4. 31-60 μ ; 5. 61-100 μ ; 6. 101-300 μ .

Figure 3b. Particle size composition of the fecal pellets of the same specimens as in 3a.

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FACTORS AFFECTING MOLLUSCAN ACTIVITY

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Years of casual observations by one of the authors have made it increasingly apparent that molluscan activity periods are governed by factors other than humidity as is commonly believed. They were observed to be active during high humidity as well as low. They have been seen moving about in high and low temperatures; at night and in the day. Predicting when they would be active (so that they might easily be collected) began to seem impossible. Times that appeared to be "ideal" would find no activity whereas other times which seemed to have "poor" conditions for activity would reveal much. The following investigation was undertaken in an effort to determine what factors affect their activity periods.

Dainton (1954) demonstrated that temperature, and not high humidity, induces locomotor activity in *Agrion limax agrestis*, a slug. We believed that this should be the case here also.

The study area

A study area was set up in the yard of one of the authors. The reasoning was that the entire area is fenced, molluscs occur there, and equipment could be left out and not be disturbed by the public. The substrate was St. Augustine grass (*Stenotaphrum secundatum*) bordered on one side by a mass of ferns (*Polystichium acrostichoides*) and on another by tiger lilies (*Lilium tigrinum*). Horsetails (*Equisetum arvense*) were growing in the angle formed by those two sides. All of these plants are planted against the house. The other two sides of the rectangular study plot were open to the yard. The remainder of the community normally occupying the area consisted of: slugs (*Veronicella ameghini*, *Limax flavus*, *Deroceras reticulatus*, *Limax marginatus*); snails (*Polygyra texasiana*, *Euglandina rosea*, *Helicina orbiculata*); lizards (*Anolis carolinensis*, *Hemidactylus tursicus*); and various arthropods, nematodes, and annelids.

Methods

The following parameters were measured each night between 9-11 pm (a time when molluscs are typically active) for a period of 8 months: (1) air temperature at 5 feet above ground, (2) air temperature at the surface, (3) relative humidity, (4) wind velocity 5 feet above ground, (5) wind velocity at

grass-top level, (6) barometric pressure, (7) % soil moisture one inch below ground, (8) % soil moisture three inches below ground, (9) rainfall for the previous 24-hour period, (10) soil pH — taken at irregular intervals, and (11) any miscellaneous activity in the area such as grass cutting.

Equipment used consisted of thermometer and a sling psychrometer for relative humidity. A hygrothermograph was left permanently in the area to serve as a reference for times when measurements were not taken. Soil moisture blocks were embedded in the soil with the terminals exposed for connection to the meter. A rain gauge, emptied each night, was also permanently installed. A small wind speed indicator, a soil pH kit, and a barometer were also used.

In addition to making all of these measurements each night, observations were also made in the neighborhood. Slugs were often active on the walks in the area and those activity periods were recorded to serve as a further verification of events happening in the study area.

The primary thrust of this investigation was towards the slug, *Veronicella ameghini* but, since other organisms were present, records were kept about their activities as well.

Variables 1-9 were subjected to a discriminant functions analysis to determine which of them are most closely associated with slug activity. In this analysis the 251 data sets (from the 251 nights on which all 9 variables were recorded) were divided into two groups: those for nights when slugs were active (62), and those for nights when slugs were not active (189). Briefly, the discriminant function technique "views" these two groups as two clusters of points in a nine-dimensional space and "looks" for the single dimension along which there is the least amount of overlap between the two groups. This dimension is specified by a linear equation on all 9 variables with each variable having a coefficient or weight, the absolute size of which corresponds to that variable's importance in separating the two groups. Thus, variables with large weights are probably more important in regulating slug activity than those with small weights.

The discriminant function analysis was carried

out on the DECsystem-10 computer of the UNO Computer Research Center using the DISCRIMINANT subroutine of SPSS (Nie et al., 1975).

The results of the discriminant function analysis are summarized in Table 1. The discriminant function is highly statistically significant ($P < 0.001$), indicating that there are significant environmental differences between nights when slugs are active and nights when slugs are inactive. The standardized discriminant weights indicate that five environmental variables are of particular significance, the two soil moisture measurements, the two temperature measurements, and wind speed at 5 ft. above the ground. The mean discriminant score for nights when slugs were active is positive and the mean score for nights when slugs were inactive is negative. Therefore, relatively high values of an environmental variable will usually be associated with nights when slugs are active if the discriminant weight of the variable is positive and with inactivity if the weight is negative. Thus,

according to the discriminant function analysis, slugs are most likely to be active when three inch soil moisture, surface temperature and air temperature are high and when one-inch soil moisture and five-foot wind speed are low. However, since the two soil moisture variables are highly positively correlated ($r = 0.968$) and their discriminant weights have opposite signs, each tends to cancel the other's effect on the discriminant function. Thus, most of the discriminating ability is contributed by the two temperature variables, both of which have positive signs, and five-foot wind speed. Relative humidity appears to be of little importance in regulating slug activity, contrary to general opinion.

Although the discriminant function is highly statistically significant, it is not entirely successful in predicting the activity status of slugs, as can be seen in the comparison of actual status with predicted status in Table 1. About 30% of the data cases (nights) were mis-classified by the function, indicat-

TABLE 1.

Standardized weights for the discriminant function, mean discriminant scores and actual activity status versus predicted activity status.

Variable	Air Temperature	Surface Temperature	Relative Humidity	5 Feet Wind Speed	Surface Wind Speed	Barometric Pressure	1" Soil Moisture	3" Soil Moisture	Rainfall
Weight	0.427	0.478	0.152	-0.442	0.242	0.031	-0.675	0.958	0.066
	$P < 0.001$								
Group	Slugs active		Slugs not active						
Mean discriminant score	0.745		-0.244						
Actual status	Predicted status		Total						
	Slugs active	Slugs not active							
Slugs active	44 (71.0%)	18 (29.0%)	62 (100.0%)						
Slugs not active	56 (29.6%)	133 (70.4%)	189 (100.0%)						

% of cases correctly classified = 70.5

ing that additional environmental factors may be involved.

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FROM THE FIRST CRUISE OF THE "BLAKE" TO THE PRESENT DAY— ONE HUNDRED YEARS OF PROGRESS IN THE STUDY OF GULF AND CARIBBEAN MARINE MOLLUSCS

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A century ago, in December, 1877, Alexander Agassiz met the U.S.C. & G.S. steamer, "Blake", in Havana Harbor. This was a happy association as Agassiz, through his experience with mining, insisted on using steel cable for the trawling and dredging. This was a big advantage over ordinary hemp rope, the method used till then, both in speed and in strength of the dredging line. It was also the start of a remarkable 30 year career of ocean research by Agassiz. I had always pictured gruff old sea dog Agassiz as standing on the bridge with a big grin on his face while the ship lurched over yet another big wave, but an excerpt from one of his letters shows that he too could feel *mal de mer*, and apparently, quite often (G.R. Agassiz, 1913).

"I am off in a few days for Mexico via Yucatan. The doctor says I must not be seasick any more for the next year, so I shall go on land and look up antiquities."

The collections of molluscs made by the "Blake" were tremendous. Their descriptions took ten years to complete (Dall, 1878, 1880, 1881, 1886, 1889). This work in the Gulf and Caribbean was continued by the USFC steamer, "Albatross", in 1884-85-86 and again in 1919. The early collections were described by Dall (1890) in a paper of moderate length.

Two expeditions were made in 1893. The steamer "Wild Duck" made a reconnaissance of the

Bahamas under the direction of Alexander Agassiz. The molluscs were reported by Dall (1894). The other cruise is usually known as the State University of Iowa Bahama Expedition, but work was also carried out along the north coast of Cuba and off Dry Tortugas. A schooner, the "Emily E. Johnson" was chartered for this expedition. Again Dall published (1896) on the molluscs collected, a rather short paper with only three new species.

The "Fish Hawk" was sent to Puerto Rico after the Spanish-American war, and made a biological survey around the island. Dall (1901) again wrote the report on the molluscs, this time with Charles T. Simpson. This report was comprehensive for it included all species known to live around the island.

The "Chazalie", a yacht owned by a wealthy Frenchman, visited the northern coast of South America during two cruises in 1895-96. Some dredging was done; also shallow water shore stations were worked. The report on the molluscs was written by Dautzenberg (1900), and included several new species.

As always, some work was being done along the shore and in shallow water by individuals. W.H. Fluck, a missionary in Nicaragua was one of these. He published several short papers in the Nautilus: Fluck (1900) and Fluck, (1905). John B. Henderson used a 15 m yacht, the "Eolis", for dredging off Miami and the Florida Keys. The "Eolis" made five dredging cruises in Florida and

Bahamian waters during 1910-1915. Axel Olsson made his first foray into Latin America in 1917. He and Karl Schmidt, the herpetologist, collected fossils at Gabb's old localities on the island of Hispanola. Olsson made many collections of Recent and fossil molluscs in the ensuing fifty years.

John B. Henderson felt the need of Caribbean shallow water molluscs to compare with the tremendous collections he was gathering with the "Eolis". He chartered a Cuban fishing schooner, the "Tomas Barrera", in 1914, and invited several naturalists to accompany him on a cruise to the western end of Cuba (1916). After this, the First World War should have put a damper to expeditions, but Nutting at the University of Iowa was not a man to let such things stop him. The second University of Iowa expedition to the West Indies took place in the spring and summer of 1918. This time a vessel was not chartered, and the group stayed on shore on two of the Lesser Antilles, Antigua and Barbados. Henderson joined this expedition, and provided a 27 foot launch and all of the dredging gear. Unfortunately, Henderson died at the early age of 52, and much of the material he collected has still not been reported on.

The next cruise of interest was the Johnson-Smithsonian deep-sea expedition on Eldridge Johnson's yacht "Caroline". This vessel was used to explore the Puerto Rico Trench with Dr. Paul Bartsch (1934a) as scientific party chief. Dredging was conducted down to 5850 m, and most of the work was done in more than 360 m. Apparently, little was published on the molluscs except for two papers on the Turridae by Bartsch (1934b) and Corea (1934). Another deep sea expedition was made by the "Atlantis" in 1938 and 1939. The work was done around the island of Cuba, mainly on the north side. Most of the dredging and trawling was done in depths of 300 to 1000 m, but there were a number of deeper stations, one reaching 4773 m. The molluscs of the two cruises were described in a series of papers by Clench and Aguayo (1938, 1939, 1940, 1941).

Shallow water work during this time included the Harvard-Grand Bahama Expedition, 1936, and the University of Oxford Expedition to the Cayman Islands, 1938. Clench was the scientific part of the Harvard-Grand Bahama expedition and reported on the collections (Clench, 1937, 1938; Clench and McLean, 1937). The molluscs of the Oxford University Expedition were described by Salisbury (1953).

World War II cut out all deep sea work from 1939 to 1945. However, an active group of Cubans started a new malacological journal, "Revista de la Sociedad Malacologica Carlos de la Torre," in 1943. The unfortunate political situation led to its demise in 1954, but there was much of interest published in the nine slim volumes. The editor in chief, Carlos Aguayo, wrote many of the articles, and short news and notes as well.

There was little activity in the immediate post war period except by private individuals. Among these were Frank Lyman, Leo Burry, who dredged to depths greater than 900 m, and Thomas McGinty. Burry published very little, Lyman somewhat more to fill his small publication, "Shell Notes", but McGinty published a series of scientific articles on his own, McGinty (1955), (Pilsbry and McGinty, 1945a, 1945b, 1946a, 1946b, 1950), and Olsson and McGinty, 1958.

The cephalopods began to receive attention from Gilbert Voss (1950, 1953, 1955, 1956, 1958). Little had ever been published on this class in the tropical western Atlantic and Voss has greatly increased our knowledge of these interesting animals. One new family, genus, and species (*Pickfordiateuthis pulchella* Voss, Family Pickfordiateuthidae) was found living in very shallow water in Biscayne Bay, Florida.

The Fish and Wildlife vessel "Oregon" began operating out of Pscagoula, Mississippi, in 1950. Two Bureau of Commercial Fisheries laboratory directors, first Stewart Springer, then Harvey Bullis, undertook the collection and preservation of many thousands of specimens of both plants and animals trawled or dredged by the R/V "Oregon" or sister ships. The "Oregon" ranged as far south as Fortaleza, Brazil, while the R/V "Silver Bay" worked in the Gulf of Mexico and Caribbean. Bullis took the molluscs as his special field of study, but has published little on them due to other demands on his time (Bullis, 1959, 1964). This work is now being continued, with the emphasis more on fisheries, by the R/V "Oregon II".

The Rosenstiel School of Marine Science, University of Miami, began an intensive study of organisms living on the sea floor. The "Gerda" was utilized in the Straits of Florida and off the Florida Keys from 1961 to 1971. The "John Elliot Pillsbury" joined "Gerda" in 1963, and continued the work much further afield. The "Pillsbury" made three successful trawls in the Puerto Rico Trench in depths to almost 8000 m. The biological work of

these vessels was under the direction of Gilbert Voss and Frederick M. Bayer. The molluscan material was reported by Bayer (1971), but much material remains for study. This collection is of particular interest since special attention was paid to the northern coast of South America and the Caribbean coast of Central America. Edward Petuch is utilizing part of the collection for his dissertation, while James Quinn has written a thesis on some of the Trochidae collected by the "Gerda".

In 1965, the Marine Laboratory, Department of Natural Resources, State of Florida, began the Hourglass Program. The stations were laid out in an hourglass configuration, and were sampled monthly for a twenty eight month period. Approximately a thousand species of molluscs were collected on the shallow shelf off the west coast of Florida. Some of this material has been published by William G. Lyons (1968, 1972), but much remains to be studied.

A program to study the continental shelf of the northeastern Gulf of Mexico was started by the Bureau of Land Management in 1974. Seasonal collections were made in 1975-76, and thousands of specimens of molluscs were collected from some 90 stations (Moore, 1977).

Shallow water work in the Caribbean continued with collections and publications from previously poorly known localities. Radwin (1969) published on a collection from the Caribbean coast of Panama. Houbick (1968) published on material he collected near Limon, Costa Rica. Rehder (1962) published a brief paper on the molluscs of Los Roques, Venezuela, to be followed by a more comprehensive paper by Work (1969). Henry Coomans has been very active in the lower Caribbean, and has published a series of papers on the shallow water fauna of the region (1958, 1963, 1972). Kaufmann and Götting (1970) wrote on the prosobranchs of the Santa Marta, Columbia, area.

A milestone in the study of the shallow water fauna was the publication of a study on the marine molluscs of Grand Cayman (Abbott, 1958). In this work, Abbott considered relative abundance, island communities versus continental type communities, and the biology of a number of the species. Several books published in recent years have been popular. The first of these, "Marine shells on the western coast of Florida" has appeared in two editions, Perry (1940), and Perry and Schwengel (1955). "Caribbean Seashells", by Warmke and Abbott (1961) is a good work for shallow marine molluscs

of Puerto Rico and the Virgin Islands, and, to a lesser extent, to the rest of the Caribbean. A check list of St. Croix, U.S. Virgin Islands, was published just prior to this by Gordon Nowell-Ustiche (1959). The Texas coast was covered by Jean Andrews (1971), and Jamaica by Michael Humfrey (1975).

A number of shell clubs were formed in the past thirty years, primarily in Florida and Texas. Many of them publish a club newsletter or journal, but one, the "Texas Conchologist," (1964-) rapidly became a scientific journal largely due to the writings of one man, Helmer Odé. The molluscan collections of the Houston Museum of Natural Science have also been greatly augmented by Odé and his fellow workers.

The Yucatan peninsula is finally attracting more attention. Rice and Kornicker (1963, 1965) published two papers on molluscs from the area of Alacran Reef, Northwestern Campeche Bank. Moore (1970, 1973) has written brief accounts of the shallow water fauna of Cozumel, while Ekdale (1974) worked on the fauna from 0-60 meters at the northeastern tip of Yucatan. The latest in this series is a paper by Susan Carnes (1975) on the fauna of a lagoon adjacent to the open sea area studied by Ekdale.

SUMMARY

The past hundred years has been a century of progress in the scientific study of marine molluscs. This progress was actually initiated by the "Blake" (the "Challenger" only made two dredging stations on the northeastern edge of the Caribbean) in 1877. Nearly all of the deeper water stations have been made by government or university vessels. Work on molluscs also shifted from amateurs to professional scientists, although gifted amateurs have continued to make worthwhile contributions.

It is obvious that much was left out of this brief history; Ruth Turner with her work on boring bivalves for instance, or the papers of Eveline and Ernst Marcus on opisthobranchs. Work on fossil molluscs by Axel Olsson, Wendell Woodring, Peter Jung, and many others was also ignored due to lack of space.

In recent years, the trend has been toward more research on ecology, physiology, and reproduction. However, the main focus of this account is on the exploration and description of the molluscan faunas of the Gulf of Mexico and Caribbean during the past 100 years. Contrary to what some might think,

this work is far from finished, and will continue for many years in the future.

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THE OCCURRENCE OF *TAGELUS PLEBEIUS* IN
A MANMADE BRACKISH WATER LAKE WITH COMMENTS
ON ITS ASSOCIATES

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INTRODUCTION

The molluscan family Solecurtidae is represented by only eight species on United States coasts (Keen, 1963; Abbott, 1974); all but two of which belong to the genus *Tagelus* Gray, 1847. In Florida's estuaries this genus is represented by two species: *T. plebeius* (Lightfoot, 1786) and *T. divisus* (Spengler, 1794). Perry and Schwengle (1955) reported *T. plebeius* from moderate depths in the littoral zone; Smith (1964) and Holland and Dean (1977) from muddy sands of shallow intertidal flats; Abbott (1968) notes that it is a rapid burrower living in muddy areas near brackish water and is edible (some members of the family are cultivated for food in Asia).

Tagelus divisus has consistently been observed in low densities in geographically diverse Gulf coast estuaries Tabb and Manning (1961) in Florida Bay;

Skyes and Hall (1970), in Boca Ciega Bay; Lyons et al. (1971) in the Crystal River estuary. We, Weinstein, Courtney, and Kinch, have found a similar situation in the Marco Island estuary. Fraser (1967) found densities of from 1.3 to 13.8 per m² in Biscayne Bay. Bloom et al. (1972) found *T. divisus* to be a "superdominant" in Old Tampa Bay while it was present at only 4% of the stations in the adjacent Hillsborough Bay which has a lower mean salinity ($\bar{X}$ = 22.2 o/oo, range 12.65 - 27.84 o/oo) Taylor et al., (1970). In each instance this species seemed to dwell in outer bay areas and did not range into the extreme "upper reaches" where fresh water inflow caused salinities to fall in the mesohaline (3 - 18 o/oo). Park (1959), in fact, termed *T. divisus* a reliable indicator of high salinity bays and sounds.

Tagelus plebeius, on the other hand, was found by Taylor et al. (1970) in 35% of the samples that

contained live mollusks, and it was noted that *T. plebeius* reached particularly high densities ($\sim 300/\text{m}^2$) at shallow (.3 - .7 m), low salinity (.74 - 3.69 o/oo) stations. They interpreted areas where it was dominant (where it represented 50% or more of all living mollusks present) to be "marginally healthy".

There is evidence in the work of Subrahmanyar et al. (1976) on the Wakulla and St. Mark's River marshes that *T. plebeius* inhabits tidal creeks and extends into the lower *Juncus roemerianus* marsh (salinities 10 - 20 o/oo). We have observed numerous large, dead shells of this species in the upper reaches of the Charlotte Harbor estuary, and similar observations were made by Michel et al. (1957) in the lower Peace River, but no live animals were observed or collected. *T. plebeius* has not been collected in the many "back bay" areas of the Marco estuary, while *T. divisus* ranked 25th in abundance among the infaunal macroinvertebrates of this seasonally hypersaline estuary (Weinstein et al., in press). In December 1976 a population of *T. plebeius* and several other estuarine organisms was discovered in the littoral zone of a land-locked, dredged borrow pit (Lake Marco Shores). The purpose of this preliminary study was to gather baseline data on this estuarine community which was isolated from tidal influence.

The Study Area

The Marco estuary is located at the upper (northern) edge of the Ten Thousand Island area of Florida's Gulf coast (Fig. 1) and has been described

by Weinstein et al. (in press). Lake Marco Shores was created in 1972 when the Deltona Corporation developed the Marco Shores Golf Course which lies in a transitional vegetative zone (freshwater *Rhizophora mangle*, *Eleocharis* sp., *Juncus roemerianus*, and ponds of *Chara* sp.) inland of the tidal red mangrove forests which dominate the area. The major soil type in the lake area consists of Immokalee fine sands and mangrove peat (Leighty, 1954) underlain in some areas by limestone caprock. Before the lake was constructed drainage was accomplished by overland sheet flow through the mangroves and/or was bled off via a small (1.52m wide x .30m deep) roadside canal to east McIlvane Bay, and also shunted via a small tidal creek under State Road 951 to the western portion of McIlvane Bay (Fig. 1). In post construction times the drainage accumulated chiefly in lake, and at some critical elevation (.61m MSD), the surface waters over-spill the lake's northwestern rim to the roadside canal. Throughout this paper water depths will frequently be related to the U.S. Coast and Geodetic Survey's Mean Sea Level Datum (MSD) for the area.

METHODS AND MATERIALS

Surface and bottom physicochemical parameters have been monitored in the lake at water chemistry station 3 (Fig. 1) since 1974 by the methods described by Weinstein et al., (in press). Periodic profiling of temperature, oxygen, and salinity were conducted at water chemistry stations 1-4 (Fig. 1) during the December 1976-May 1977 period using a Beckman Model RS5-3 salinometer for temperature and salinity measurements and Winkler titration and a YSI Model 54 dissolved oxygen meter for temperature and dissolved oxygen values. On 20 January 1977 an overnight continuous profile of temperature at water chemistry station 1 to a depth of -3.50m in .30m increments was made using a YSI Model 47 scanning Tele-thermometer coupled to a YSI Model 80A Single Channel Laboratory Recorder. Depth profiling of the lake was accomplished during the period October 25-26, 1976, using a Raytheon Survey Fathometer Model DE-719B.

A system of stratified random sampling was employed for collection of the fauna since the physicochemical data suggested a stratification in the lake and since substrates also appeared to vary. In January 1977 when the lake water level was at maximum elevation a transect was established from

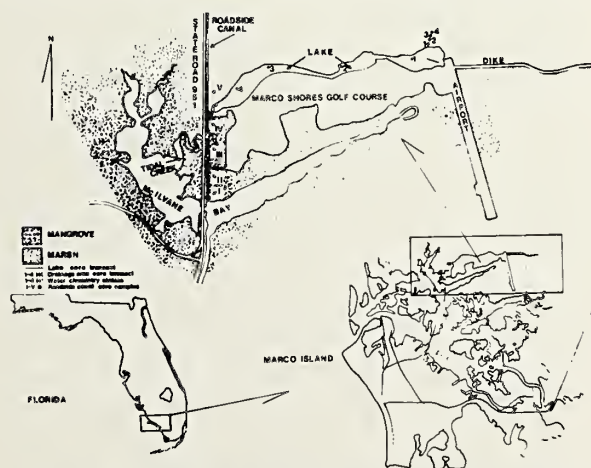


Fig. 1. A map of the study area showing station locations.

the shore through the littoral zone to a depth of 3.04m (-2.59m MSD) on the eastern end of the lake, and .30m contour intervals were sampled for macroinvertebrates (those retained by a .701mm sieve). Two coring devices ($1/64 \text{ m}^2$) were used depending on water depth: a plug corer similar but smaller than that used by Taylor and Saloman (1968); and, a post-hole digger similar to that used by Baird et al. (1971). A second series of lake transect samples were taken in April 1977, and represent the yearly low lake level. Core transects in the drainage area above the lake (station 1-4, Fig. 1) and the roadside canal (stations I-V, Fig. 1) were used to determine the similarity of lake faunal components to adjacent areas. Substrates were collected using a 2 inch (I.D.) plexiglass tube and fractionated with a set of U.S. Standard Sieves. The sediment fractions were ashed in a Thermolyne Type 1500 muffle furnace for one hour at 550°C to determine per cent organic content.

RESULTS

Physico-Chemical Parameters

The average depth of the lake was 3.0m with pockets of water 10.0m deep. Regression analysis of water chemistry station pairs indicated that one station could be used to reliably represent the lake as a whole with a high degree of confidence ($r = .900$). The development of a layered system is demonstrated by comparing temperature and salinity profiles with depth for station 4 between the years 1973 (construction completed) and 1976 (Fig. 2). In 1973 a halocline had already begun to develop at the 4.57m depth ($>50 \text{ o/oo}$ at 9.14m) and with the evaporative effect of the lake's first dry

season even the surface salinity values were in the 23-25 o/oo range. In June 1974 the Marco vicinity received .32m of rainfall, and the input of overland runoff from this large rainfall apparently accelerated what had been a gradual freshening process. Between May and July 1974 the surface salinity decreased from 29.3 o/oo to 5.7 o/oo. Surface salinities for 1976 (Fig. 2) were still at or slightly below 5 o/oo, but the stratified layer began at 1.82-2.13m depth. While no thermocline was present in 1973, one was well developed at the 1.21-2.13m depths in 1976.

A variety of chemical parameters was measured in profiles at the lake core sampling transect. At the chemocline (between 1.82 and 2.13m) a twofold increase in conductivity (10.56 to 25.40 mmho/cm) salinity (7.66 - 17.46 o/oo) and NH_3 ($88.0 - 344.1 \mu\text{g/l}$) was further evidence of the degree of stratification present. Findenberg (1965) has noted that the steeper the chemocline density gradient, the less the transport by turbulence that can occur across this boundary when the mixolimnion (upper layer) is turning over. Under such conditions the monimolimnion (lower layer) traps nutrients and becomes strongly anaerobic. An interesting observation in data collected on 2/9/77 indicates that considerable production (chlorophyll $a = 82.77 \mu\text{g/l}$) was taking place in the upper monimolimnion. Frey (1967) has pointed out that in a two layered system, where a thin layer of relatively fresh water overlies saline water, the saline monimolimnion can be warmed directly by sunlight to high temperatures providing a "greenhouse effect" where light energy freely enters, but is converted to longer wavelengths increasing net absorbance. The lake has become meromictic, a situation in which some lake water remains partly or wholly unmixed with the main water mass at the circulation periods (Hutchinson, 1975). An unprecedented cold spell during the period 1/19 - 1/21/77 provided an opportunity for observing the degree of mixing that could be induced by a natural temperature depression. Even though air temperatures at the lake reached to -2.2°C and the thermocline was compressed to the 2.29 to 2.90m depth interval, temperature in the monimolimnion remained unchanged. Tides in the Marco vicinity are of the mixed variety with diurnal inequalities. Fisher Porter recording tide gauges were emplaced at the study site and at the mouth of the roadside canal where it joins McIlvane Bay. Van de Kreeke (personal communications) has an-

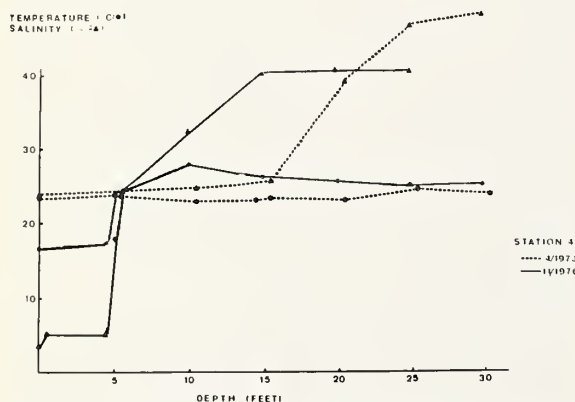


Fig. 2. A comparison of temperature and salinity profiles for 1973 and 1976.

alyzed the data from these gauges for several months and has found no tidal penetration of the lake. A graph of the lake gauge does show long term evaporation (1/1 to 1/15/77) and the containment of some surface runoff (1/16/77) after a .08m rain on 1/15/77. The sediment analysis revealed an organic composition ranging from .01% at the shore 88 μ fraction to 4.4% at the .15m 500 μ fraction. The mode for inorganic fractions was in the 149 μ or 297 μ fractions except at the 1.52m depths where peak abundance was evenly distributed among the three smallest size fractions (149 μ , 88 μ , and 88 μ). The increasing dominance of the 88 μ fraction in areas below the chemocline may combine with chemical processes to limit distributions.

Biota

A total of 2,716 individuals representing over 22 species were collected in the lake. Three species represented 89% of the total numbers of individuals collected: *Tagelus plebeius* 42.0%; the polychaete, *Laeonereis culveri*, 34.0%; and an unidentified Chironomid insect larva, 13.1%.

A plot of the Shannon-Weaver (1949) index of diversity for each contour interval (Fig. 3) reflected the changes observed in the community dominants. For the January samples minimal diversities were found at the shore-water interface (+.46m MSD) which was occupied by only *Laeonereis*; at the .30m depth (.09m MSD) where neither the Chironomid nor *Laeonereis* were well represented; and at 2.1m (-1.68m MSD) where only the Chironomids were well represented. Diversity at all levels above -1.98m (MSD) increased in the April

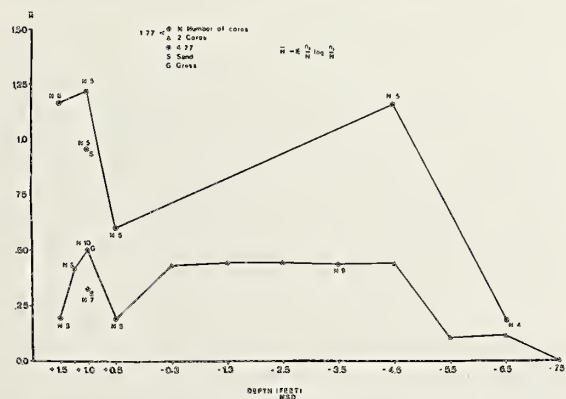


Fig. 3. The Shannon-Weaver indices at selected lake stations.

samples reflecting the decreased dominance of *Laeonereis*, and the Chironomid. Diversity was low, as might be expected for brackish water, falling just below exterior "bay head" station diversities which range from .65 to 1.32 locally (Weinstein et al., in press).

Notes on the environmental factors of selected species follow:

Phylum Mollusca: Assimineidae Fleming, 1828

A number of these minute (2.5mm) brackish-water gastropods were taken in grass at the .15m depth.

Phylum Mollusca: *Mytilopsis leucophaea* (Conrad, 1931)

These brackish water bivalves (Abbott, 1974), though infrequent in the collections, have been observed in large numbers in the lake during the summer months when they are attached to any wood in the water from the surface to .30m deep. Odum (1971) found this species abundant in the upper reaches of Florida's North River estuary during the summer months, but reported that it died off in the winter dry season.

Phylum Mollusca: Teredinidae

Although not collected in samples, members of this group (shipworms) riddled the supporting wood of lake tide gauge stands in August 1976.

Phylum Mollusca: *Tagelus plebeius* (Lightfoot, 1786)

Figure 4 depicts the distribution of *Tagelus plebeius* with depth. The center of its distribution in January 1977 was from a water depth of -.08m (.38m MSD) to -1m (-.40m MSD) with a peak in a grass bed at the -15cm (.3m MSD) depth. There seemed to be a slight resurgence of the population

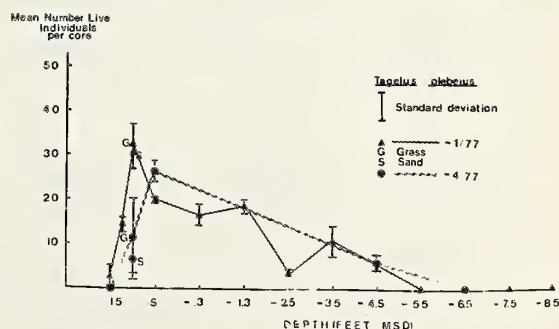


Fig. 4. The distribution of *Tagelus plebeius* with depth.

at the -1.5m depth, but no live *Tagelus* were found below 2m. With the dry season drawdown of lake waters much of the shallow area was exposed and the center of the distribution of *T. plebeius* showed a corresponding shift lakeward.

Arbitrary size classes (length) of .5cm are represented as per cent of the total live *Tagelus* catch as are dead intact shells (both valves attached) as a per cent of the total dead catch at several stations in Figure 5. In the January 1977 samples when the lake was at its maximum elevation 12 live clams were found at the shore-water interface (+.46m MSD) and 57% of these were between 2.0 and 2.5cm in length. It should be noted that this station had a large number of dead intact shells present which were normally distributed among the size classes. The April sample at this elevation showed 100% mortality associated with the lowered lake level. The larger size classes of live *Tagelus plebeius* dominated areas shallower than 1.5m in depth (-1.07m MSD) while the smaller size classes dominated samples from the 15cm depth or below. No living *Tagelus* were found below the 2m (-1.37m MSD) depth. There was a decrease in the numbers of dead clams of the smaller size classes with depth, and this is attributed to the probable rapid remineralization of shells by the low pH's of

these lower depths. A peak in the dead to live shell ratio was found at -.76m and -1.37m MSD and probably evidence the inability of the adults to cope with the chemocline.

Phylum Annelida: *Laeonereis culveri* (Webster, 1879)

This species ranked second in overall abundance to *Tagelus plebeius*, but was only found in substantial quantities at the shore-water interface (2,739 individuals/m²) and at a depth of 1.83m (832 individuals/m²) but did not persist below the chemocline. Subrahmanyar et al. (1976) found *L. culveri* densities of as high as only 26/m² in upper *Juncus roemerianus* marshes while Hartman (1951) noted that this species is common and gregarious occurring throughout the Gulf of Mexico in sandy or mud-sand beaches at high or low tide levels. She also observed that it is the most abundant burrowing form on the salt flats of Aransas refuge, is resistant to low salinity and temporary drought, and burrows perpendicularly in the substrate to a depth surpassing the animal's length. Fotheringham and Brunenmeister (1975) have observed, however, that after prolonged rains it can be found exposed and immobile on the mud surface. This species persisted in the littoral zone of Lake Marco Shores as long as the soil remained damp.

Phylum: Annelida: *Nereis falsa*

This polychaete was most abundant at depths of from 8 to 15 cm and particularly in the grass.

Phylum Annelida: *Polydora ligni* (Webster, 1879)

Only 20 specimens were collected. These annelids constructs fragile tubes of silt on tidal flats. Reproduction is rapid.

Phylum Arthropoda: *Grandidierella bonnieroides*

This species was collected in densities of 30/m² at depths of less than 1.5m. Barnard (1969) noted that this littoral, brackish water is circumtropical in warm temperate zones. Subrahmanyar et al. (1976) called it abundant (3/m²) in lower and upper *Juncus roemerianus* marshes.

Phylum Arthropoda: *Taphromysis bowmani* Bacescu, 1961

While these mysids occurred infrequently (5/m²) in our collections, Brattegard (1969) suggests that this species is characteristic of brackish water in

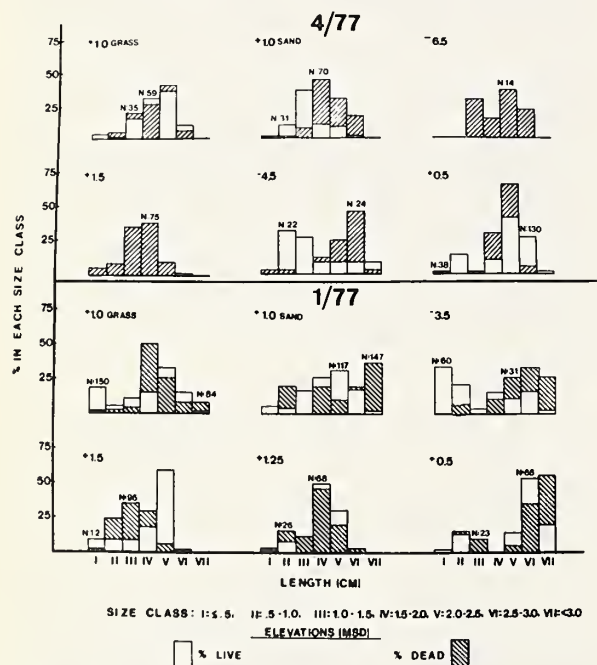


Fig. 5. Size class distribution of *Tagelus plebeius* (living and dead) at selected lake stations.

Florida and that it may also occur in fresh water. This species was found by Subrahmanyar et al. (1976) in the Wakulla lower marshes.

Phylum Arthropoda: Chironomidae

These midge larva were bright red and appeared to have silt in their guts. This type of coloration is characteristic of the more abundant species which live in water where the concentration of dissolved oxygen is very low. They have been observed in concentration of over 50,000/m² in certain lakes (Pennak, 1953). They are chiefly herbivorous, feeding on algae and organic detritus. In Lake Marco Shores these larvae are found throughout the mixolimnion and chemocline to the top of the monimolimnion, but none were found below 2.5m. It is not uncommon for whatever benthos that is present in meromictic lakes to be concentrated near the top of the monimolimnion with midge larvae being dominant, and it is equally common in the more severely chemically stratified lakes for there to be no benthos at all in the monimolimnion (Frey, 1967).

DISCUSSION

The origins of the dense monimolimnion of this meromictic lake cannot be resolved in this paper. It is, however, probably that evaporation of the surface runoff carrying salts from the watershed during subsequent rainy seasons increased the salt concentration of the lower layer. Mixing in the chemocline, although apparently minimal, could have contributed to a gradual freshening and downward movement of the mixolimnion.

In a historical perspective the area would be considered fresh to brackish. It is well known that brackish waters are poor in diversity when compared with similar marine or fresh water regions (Remaine and Schlieper, 1971). Certain marine species (e.g., *Rangia cuneata*) are, however, capable of exploiting the estuarine upper reaches where low salinities are both physiologically and ecologically optimal (Hopkins et al., 1973). We found no *Tagelus plebeius* in the cores from the roadside canal, but the clam was found at a distance of 61m on the core transect above the lake. The seasonally flooded saltern-Eleocharis zone above the lake has pockets of dense concentrations of large (2.5cm) *T. plebeius* during the dry season. Castagna and Chanley (1973) examined the salinity tolerances of a number of

marine bivalves including *Tagelus plebeius*. They were able to culture larvae at salinities of 20 o/oo and 30 o/oo and they showed that up to 33% of the adults could survive direct transfer from areas of intermediate salinity (20 o/oo) to waters of 2.5 o/oo, but they noted that populations suffered considerable stress in salinities below 10 o/oo. Their results, therefore, indicate that a seed population of *Tagelus plebeius* from pre-development times in this brackish area could be expected to have had a very good chance of surviving the low salinities created by the lake impoundment. It must be concluded that *Tagelus plebeius* and many of its associates, inhabiting the fresh marshes prior to the construction of the lake, found conditions in the lake adequate to complete their respective life cycles isolated from the Gulf of Mexico. This conclusion is based on the following observations: 1) The presence in April 1977 surface plankton tows of *T. plebeius* pediveliger larvae in densities of 4 individuals per liter; 2) The presence in these same tows of bloom levels of the planktonic diatom *Chaetoceros* sp. which could serve as an adequate food supply 3) Small sizes of *Tagelus plebeius* (< .5 cm), *Laonereis culveri* and the chironomid larvae; and 4) ovigerous females of the amphipod species *Grandiderella bonnieroides* and the caridean shrimp *Palaemonetes paludosus*. The population of *Tagelus* responded to the lake draw-down by rising in its burrows to the substrate surface and with exposure of the bottom the clams were left gaping with one half of the length of their valves above the substrate. Just prior to and during this emergence the population was heavily preyed upon by willets and other smaller shore birds. Abundant racoon tracks and piles of dead shell indicate that these omnivores also found *Tagelus plebeius* to their liking. This estuarine clam has apparently adapted well to the rigorous environment of the coastal transition zone growing to a length of 2.5cm in a single 6 month wet season. It may yet prove to be an important link in the food chain of an area noted for low species diversity.

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THE PLEUROCERIDAE AND UNIONIDAE
OF THE
UPPER SOUTH FORK HOLSTON RIVER IN VIRGINIA

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For about a decade we have devoted a part of each year's field work to making systematic collections in the rivers draining the "high country" on either side of the main stem of the Mississippi River. By "high country" we refer to the southern Appalachian Mountains and Cumberland Plateau to the east and the Ozark Plateaus and Ouachita Mountains to the west. Actually, our objective is to obtain samples of pleurocerid snails and naiad mollusks from those parts of those river systems that still retain at least a substantial fraction of their original fauna. We have concentrated upon those streams or stream segments that have never been studied, and areas where it appears that earlier studies were not as comprehensive as desirable.

This study concerns the distribution of pleurocerids and unionids in the South Fork Holston River, Virginia, above the South Holston impoundment. This is a straight-line distance of about 33 miles and represents 18 collection sites spaced roughly two miles apart (Fig. 1). Voucher specimens of all species are deposited in The Ohio State University Museum of Zoology.

Publications on the mollusks of the Holston River by Lewis (1871), Boepple and Coker (1912), and

Remington and Clench (1925) refer to the fauna of the Holston far downstream below the confluence of the North, Middle and South Forks of the Holston. Adams (1915) included stops at Friendship, Alvarado (Barron), and Damascus in his search for *Io fluvialis* in 1901 and concluded that it "does not occur...in the South Fork, above the junction of the two streams near Barron, Va."

South Fork Holston River has its origin in the confluence of Slemple and Cressy Creeks at the village of Sugar Grove, Smyth County, Virginia. From this point it flows southwest down its valley to the slack water of South Holston impoundment. The South Fork valley lies in the Ridge and Valley Province adjacent to that part of the Appalachians characterized by the outcropping of metamorphic and igneous rocks. Its southern tributaries contribute waters largely from quartzite and crystalline rocks. These rocks and the soils formed from them are characteristically low in calcium, thus constituting a possible limiting factor for mollusks that have a relatively high calcium requirement. Tributaries from the north are few, small, and flow over calcareous rock formations, mainly dolomite, as does most of the main stream. The South Fork

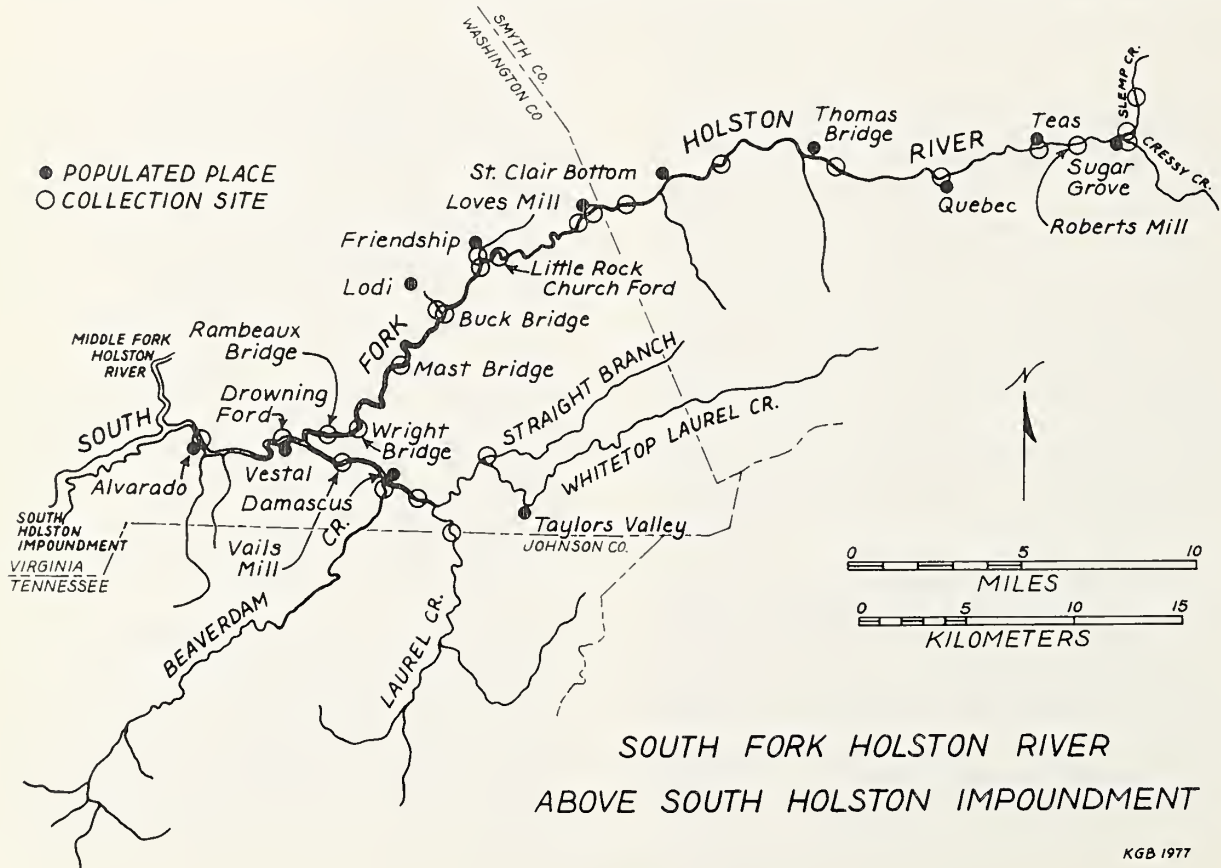
Holston appears to differ from both the North and Middle Forks in its reduced exposure to calcium-bearing substrates.

Sharing the same valley, but flowing northeast, is Cripple Creek of the New River system. Although we have yet to sample this stream, we would predict, on the basis of past studies (Stansbery and Clench, 1974; 1975) that both the pleurocerid and unionid faunas, in spite of almost identical topography and bed rock, would consist of different species and less variety. This decreased diversity has characterized the sites we have collected in the New River tributaries which interdigitate with the headwaters of the Tennessee River system. We believe these differences are due to the lack of access of ancestral forms and not to the lack of a suitable environment.

Previous records from the study area consist of a single specimen of *Fusconaia bamesiana* (Lea, 1838) from Laurel Creek at Vails Mill taken by Adams in 1901 and a combined total of 13 naiad species collected at our lower-most site, Alvarado, by Adams in 1901 and Ortmann in 1913 (Ort-

mann, 1918). These records were used along with our own to construct a table of species distribution. An examination of this table reveals several interesting phenomena, some expected and some not:

1. The tributaries from the crystalline rock part of the drainage had only one species of pleurocerid, *Goniobasis simplex* (Say, 1825) and one species of naiad, *F. bamesiana*. Goodrich (1950) characterized the habitat of this and closely related species and noted, "It may be in time the shells remaining will be those individuals that have taken to mountain climbing." While *G. simplex* was found living at all 10 tributary sites, *F. bamesiana* is known from only one, the lowermost site on Laurel Creek, and only from the collecting of Adams in 1901. We found no bivalves in any of the tributaries in this study. *Pleurocera uncialis* (Haldeman, 1841) was taken with *G. simplex* from near the mouth of a tributary near Friendship. This creek flows from the



KGB 1977

Figure 1

calcareous side of the South Fork and is the only relatively large tributary from this limestone area.

2. The four pleurocerid snails living in the South Fork proper are the same species found in the North and Middle Forks (Stansbery and Clench, 1974; 1975). *Goniobasis simplex* was found at the uppermost 12 of the 16 collection sites here and was the principal headwater species in the forks. The distribution tables indicate that *Spirodon patula* Anthony, 1860, usually comes in downstream from the uppermost occurrence of *G. simplex* and continues further downstream than this latter species. *Pleurocera uncialis* and *Anculosa subglobosa* typically appear for the first time farther downstream and tend to persist in this direction until eliminated by pollution or impoundment.

3. No pleurocerid species were found at the lowermost two sites in spite of seemingly ideal habitat. This is just above the impoundment and is a repetition of our experience in the Middle Fork study. The naiad species also become noticeably fewer as an impoundment is approached from the upstream direction. Notably this is in an area that is not covered with slack water at the high pool stage of the impoundment. The correlation seems clear but the cause and effect relationship is not apparent to us.

4. Naiades were absent from the uppermost eight miles of South Fork. The only bivalve species found in the comparable part of the Middle Fork was *Lasmigona holstonia* (Lea, 1838), but this species appears to be absent from the South Fork. *Lasmigona holstonia* is an extreme headwater species where it is found and occupies stream habitats similar to those of *G. simplex*. The origin of these isolated headwater populations and the factors responsible for this restriction are not known.

5. As the stream develops from a nearly continuous riffle to the familiar riffle-run sequence farther downstream, *Villosa vanuxemi* (Lea, 1838) and *Villosa iris nebulosa* appear and rather quickly become the most common

naiades, if not the only ones present. These were the only two bivalve species found in the upper South Fork above Friendship, about 65% of the stream length. Just below Friendship the naiad diversity increases sharply from two to six species. This is essentially the same phenomenon observed in the Middle Fork where the same two species suddenly become part of a nine species fauna. Stansbery and Clench (1975) have cited stream temperature and available calcium as possible limiting factors in the upstream direction. Other possible factors limiting mollusk distribution in headwaters include available nutrients, substrate stability, and intensity of predation.

The presumed restriction of the range of the fish host is so often given as the only reason for the restricted range of naiad mollusks that other possible limiting factors are commonly ignored. We do not doubt the effectiveness of host range in this matter, but we believe that other factors should also be considered until the evidence becomes something approaching "conclusive."

For example, the amount of available calcium apparently increases going downstream in the South Fork. Since there is most probably a different minimum threshold of calcium necessary for the survival of each of the various species present in the river, those which require the least concentrations of calcium could, other factors being favorable, extend farther upstream than species requiring high calcium concentrations.

Hopefully our observations will inspire other investigators to reconsider some of the less obvious factors that may be responsible for determining the distribution of mollusk species.

ACKNOWLEDGEMENTS

We would like to thank Carol Stein, who reviewed the manuscript; Constance Boone, who helped us with the 1974 field work; Kathy Borrer, who drew the map of the area collected; and Denise Schoster, who prepared the table of species distribution records and typed the manuscript.

SPECIES RECORDED	TRIBUTARY COLLECTION SITES													MAIN STEM COLLECTION SITES													Frequency of Occurrence	Range of Distribution
	Slomp Cr., at Sugar Grove, 1974	Slomp Cr., 2 mi. NE Sugar Grove, 1974	Cressy Cr. at Sugar Grove, 1974	trib., 1 mi. SSW Friendship, 1970	trib. at Buck Bridge, 1968, 1974	Laurel Cr., 2 mi. SE Damascus, 1974	Laurel Cr., 1 mi. SE Damascus, 1968	Laurel Cr. at Vails Mill*, 1901	Straight Br., 2.7 mi. ENE Damascus, 1970	Beaverdam Cr. at Damascus, 1968	Roberts Mill, 1974	Teas, 1974	Quebec, 1974	0.7 mi. above Thomas Bridge, 1974	2.7 mi. W Thomas Bridge, 1974	1.4 mi. SW St. Clair Bottom, 1974	Love's Mill, 1974	3.0 mi. ENE Friendship, 1974	Little Rock Church Ford, 1974	1.0 mi. SSW Friendship, 1970	Buck Bridge, 1968, 1974	Mast Bridge, 1974	Wright Bridge, 1968, 1974	Rambaux Bridge, 1974	Drowning Ford, 1970, 1974	Alvarado (Barron Station), 1901, 1913, 1974		
FAMILY UNIONIDAE (Fleming, 1828) Ortmann, 1911. Subfamily Anodontinae (Rafinesque, 1820) Ortmann, 1910. <i>Pegias fabula</i> (Lea, 1838). <i>Lasrignona costata</i> (Rafinesque, 1820). <i>Alasmidonta marginata</i> Say, 1818. <i>Alasmidonta viridis</i> (Rafinesque, 1820). Subfamily Amblesinae (Rafinesque, 1820) Morrison, 1955. <i>Fusconia barnesiana</i> (Lea, 1838). <i>Pleurobema oviforme</i> (Conrad, 1834). <i>Elliptio dilatatus</i> (Rafinesque, 1820). Subfamily Lampsilinae (von Ihering, 1901) Ortmann, 1910. <i>Psychobranthus subtentum</i> (Say, 1825). <i>Actinonaias pectorosa</i> (Conrad, 1834). <i>Medionidus conradicus</i> (Lea, 1834). <i>Villosa iris nebulosa</i> (Conrad, 1834). <i>Villosa vanuxemi</i> (Lea, 1838). <i>Lampsilis fasciola</i> Rafinesque, 1820. <i>Epioblasma walkeri</i> (Wilson & Clark, 1914).	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	2	0	0	2	6	5	5	9	7	1	13	4	8
Total Naiad Species Recorded	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	2	0	0	2	6	5	5	9	7	1	13	4	8
FAMILY PLEUROCIDAE Fisher, 1887. <i>Pleurocera uncialis</i> (Haldeman, 1841). <i>Goniobasis simplex</i> (Say, 1825). <i>Spirodon patula</i> Anthony, 1860. <i>Anculosa subglobosa</i> (Say, 1825).	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	ao	6	6
Total Pleurocid Species Recorded	1	1	1	2	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	3	3	3	2	3	0	0	22	22
																											5	10
																											4	5

x = this study, 1968-1974 o = Ortmann, 1913 a = Adams, 1901 * Adam's "Mock Mill"

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APPLICATION OF AN ACETATE PEEL TECHNIQUE TO ANALYSIS OF GROWTH PROCESS IN BIVALVE UNIONID SHELLS

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INTRODUCTION

Since many southeastern prehistoric sites were evidently occupied on a seasonal basis, archeological research has been increasingly concerned with the patterning as well as the nature and extent of occupation of aboriginal settlement systems. At the present time, few techniques of any kind are available for determining the season of occupation and resource utilization of prehistoric sites. Traditional archeological analysis has relied on a range of techniques from forthright speculation based on the presence or absence of certain animal or plant species at sites to a more empirical study of growth increments on fish scales. Many archeological sites in the southeastern United States characterically contain large quantities of shells which were utilized and discarded by prehistoric peoples. The unionid bivalve shells in these deposits presumably reflect the annual and seasonal growth increments of the mollusks which produce them. If a technique could be devised which would furnish a reliable estimate of the season at which the shells of these ancient animals were harvested, it would also be a most useful archeological tool. This paper is a progress report on an attempt to determine the season of death of

unionids by applying an acetate peel technique to the analysis of the growth process in the shells. Since this study is primarily attempting to test the usefulness of the technique with respect to freshwater unionid shells, only modern-day shells have been examined to date.

GROWTH AND FORMATION OF THE SHELL

Some of the most intensive shell growth studies on unionid mussels took place early in this century as a result of the button industry (Lefevre and Curtis, 1912; Isely, 1914; Coker, *et al*, 1921; Chamberlain, 1930). These studies found that if the margin of the mantle, where shell growth occurs, withdraws within the shell to such an extent that its former continuity with the distal edge of the shell is severed, then, when growth resumes, there is apt to be an overlapping or doubling up of the outer two shell layers. This overlapping, and the resultant change in rate of calcium carbonate deposition, is often manifested by dark bands. These may be formed annually (during the winter season) or as the result of more singular disturbances such as extreme water temperature fluctuation and/or temporary stranding of the animal. Interruption increments corresponding to the winter season differ

from those corresponding to unfavorable conditions in that the latter appear to have only single duplications of the outer shell layers while the former has several. Chamberlain (1930) argues that these duplications can be distinguished by careful microscopic examinations of cross sections of the prismatic layers of the shells. With the acetate peel technique, I am testing Chamberlain's conclusions.

PREPARATION AND ANALYSIS OF SAMPLES

The technique is based on work done in New Zealand with marine mollusks by Coutts (1970) and the procedure is summarized by Kummel and Raup (1965). Recent bivalves were collected throughout the year from various locations in Arkansas. These locations (the Upper Buffalo River, the Upper and Lower White River, the Lower St. Francis River, and several smaller permanent streams) correspond with the locations of numerous archeological sites, many of which show evidence of extensive molluscan exploitation during prehistoric times.

Shell growth was studied by means of acetate peels. After embedding the shells in dental stone (a dense plaster), I cut them at right angles to the growth increments (along the umbonal axis), then ground and polished them to obtain smooth, flat surfaces. These surfaces were etched with 5% hydrochloric acid for 15 seconds to one minute. In some cases, Alizarine Red-S was used to stain the surface producing negative surface impressions of the cross sections. These peels were examined at magnifications ranging from 10 to 200 power.

The determination of the season of death of a unionid is accomplished by measuring the distance between the annual growth recession rings. Chamberlain (1930) found that in many species, the distance between rings decreases logarithmically with respect to age. Therefore, it should be possible to extrapolate the distance from the last ring to the next one which would have been formed if the organism had lived. By comparing this calculated distance to the actual edge of the shell, the time of year when death occurred could be estimated.

RESULTS AND CONCLUSIONS

To date, acetate peels of approximately 75 unionids representing 13 species have been made.

No list of species is provided at this time due to the rather generalized results presented here; however, a complete list of verified identifications will be published later. The peels have possibly revealed the presence of two kinds of growth arrest markers: (1) the annual interruption ring with its several duplications of the outer shell layers; and (2) the intra-annual interruption ring with its single duplication (Plates I, II, and III). Difficulty, however, has occurred in attempting to distinguish between these two markers in all of the specimens analyzed. For instance, it has become apparent that some unionid bivalve shells are better suited for this type of study than are others. Although bivalves of the genus *Quadrula* have thick shells and are often preserved in archeological deposits, their relatively long life spans and slow shell growth beyond the juvenile stage result in the production of growth lines so close together that differentiation by means of this technique is often difficult. The evidence to date suggests that the faster growing species of the genus *Lampsilis* might prove promising; however, further study will be necessary to determine the more suitable species for shell growth analysis. It has been also observed that the growth interruption increments tend to be narrower and less distinct toward the hinge of the valve (i.e., those formed during juvenile growth), resulting in greater difficulty in distinguishing the two types of rings.

ACKNOWLEDGEMENTS

Identifications were verified by Dr. Louise Kraemer of the University of Arkansas zoology department. Voucher specimens available at the University of Arkansas Museum, Fayetteville.

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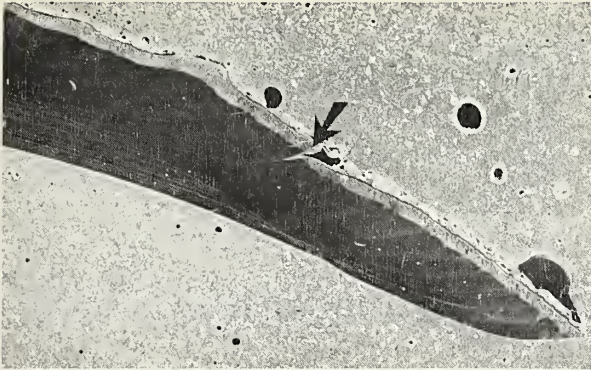


Plate I-A. An acetate peel of the cross section of the shell of a *Quadrula pustulosa* (growth increment indicated by arrow).

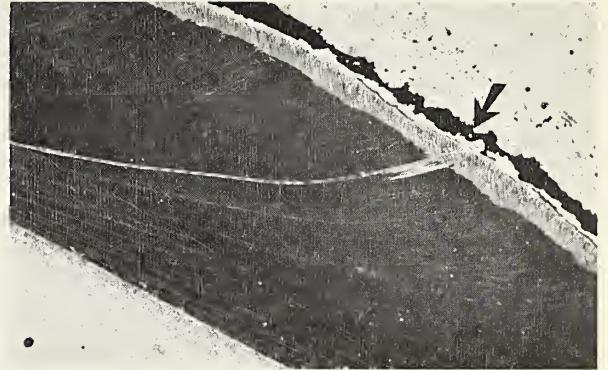


Plate I-B. An enlargement of an acetate peel of the cross section of the shell of a *Quadrula pustulosa* (not the same specimen as above) showing a prominent annual growth recession increment.

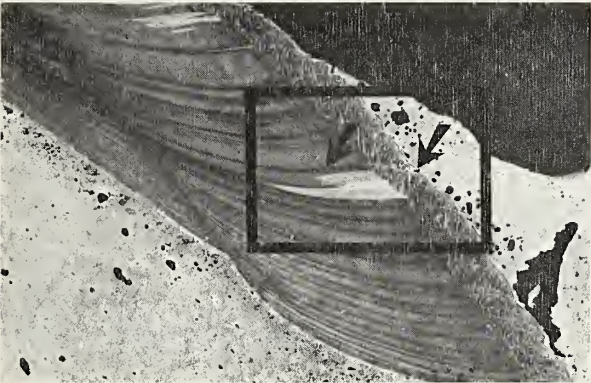


Plate II-A. An acetate peel of the cross section of the shell of a *Uniomerus tetralasmus* near the distal margin (enlargement section shown below).

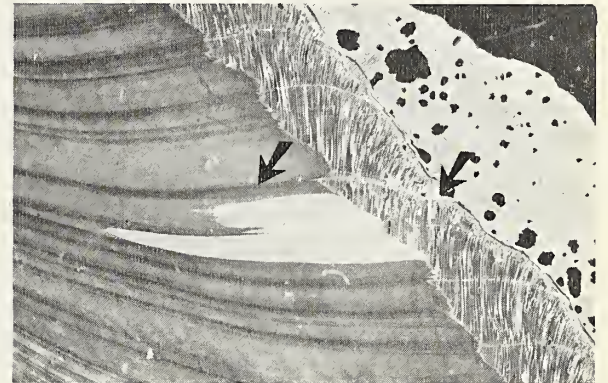


Plate II-B. An enlargement of an acetate peel of the cross section of the shell of a *Uniomerus tetralasmus* (same specimen as above) showing growth recession increments as manifested in the prismatic and nacreous layers.

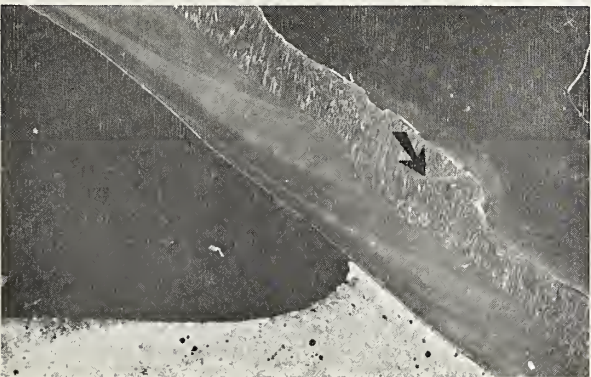


Plate III-A. An acetate peel of the cross section of the shell of an *Arcidens confragosus* showing growth recession increments in the prismatic layer.

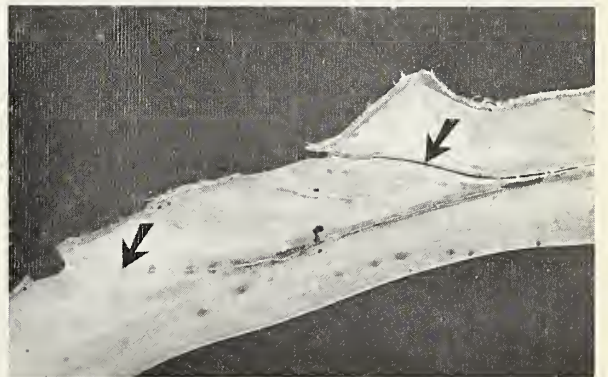


Plate III-B. An acetate peel of the cross section of the shell of a *Quadrula quadrula* showing several prominent growth recession increments.

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VILLOSA LIENOSA (CONRAD, 1834) IN OHIO

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Villosa lienosa (Conrad, 1834), a naiad species common in Gulf coastal states, has been collected in several midwestern states but has never been reported as occurring in Ohio. Recently, we and other collectors at The Ohio State University Museum of Zoology (OSUM) have found populations of this species in five separated streams in the southern third of Ohio (Fig. 1). These streams are East Fork of the Little Miami River, Whiteoak Creek, Scioto Brush Creek, Little Salt Creek and one tributary of Symmes Creek. These five streams are all relatively small (2-5m wide) and of low gradient (less than 12 ft./mi.) (Krolczyk, 1960) with sand and/or mud bottoms where the *V. lienosa* specimens were collected. These habitat observations are consistent with previously recorded habitat descriptions for this naiad (Clench and Turner, 1956; Parmalee, 1967).

Literature records of northern populations of *V. lienosa* exist for Illinois (Baker, 1922), Indiana (Blatchley and Daniels, 1903; Goodrich and van der Schalie, 1944) and Kentucky (Wilson and Clark, 1914; Ortmann, 1926; Stansbery, 1965) but not for Pennsylvania. The OSUM has one lot from the Hughes River in West Virginia, which appears to be a new record for that state. All of these sites are plotted on Fig. 1.

We have compared the known distribution records of *V. lienosa* with several stream-related factors in an attempt to explain why this naiad does not occur throughout the upper Ohio River system. Blatchley and Daniels (1903) mention that *V. lienosa* was common in the canal and White River at Indianapolis. Canals fit our concept of the habitat of *V. lienosa* and, approximately 125 years ago, canals connected the major midwestern drainage systems, affording potential access to more northern streams in several states. Our comparison

of the canal systems and the distribution records for *V. lienosa* failed to reveal any clear relationships.

A similar comparison was made of the distribution records for *V. lienosa* with bedrock composition. Midwestern bedrocks vary widely in their pH characteristics and are deposits of most Paleozoic periods. We found that the range of this naiad species extends over all bedrock types present in this area.

Geologic evidence suggests that, prior to the Pleistocene, midwestern stream drainage patterns were considerably different from those of the present. We compared the distribution of *V. lienosa* with the Teays drainage, the most widely accepted concept of a pre-glacial drainage pattern. The correlation we found was best for parts of streams south of the glacial boundary—areas where drainage patterns have changed very little.

Our final attempt was to correlate the distribution pattern of *V. lienosa* with the glacial patterns of the midwest. Three of the sites in Ohio are located south of any glacial boundary; the other two sites are located south of the Wisconsin glacial boundary, but within the area once covered by the Illinoian glacier. In Indiana, four sites are south of the Wisconsin glacial boundary (with one site in unglaciated terrain), while the other four are north of the Wisconsin boundary. In the state of Illinois the only records of which we are aware are those from the Big Vermilion River (Baker, 1922), a small stream located in a Wisconsin-glaciated area.

Goodrich and van der Schalie (1944) state that southern Indiana marks the northern limit of the range of *V. lienosa*. We have extended the known range of this species east into Ohio and West Virginia, and slightly to the north in Illinois, but we have not changed their basic observation that this area constitutes the northern limit of the range. We



Figure 1. Localities at the northern edge of the range of *Villosa lienosa* (Conrad, 1834) taken from published accounts (see text) and from specimens at the Ohio State University Museum of Zoology. The long- and short-dashed line indicates the Wisconsin glacial boundary; the short-dashed line indicates the Illinoian glacial boundary.

have not examined specimens housed in other museums, nor have we collected widely in small streams outside of Ohio. Additional records from either of these sources would provide a better concept of the complete distribution pattern. Known records indicate that the distribution pattern of *V. lienosa* has at least some relationship with the Wisconsin glacial boundary: every known collection has been taken south of, or only slightly north of, this glacial feature. We are unaware of any characteristics of Wisconsin-glaciated areas which would preclude the introduction of *V. lienosa* by some fish host, or which would prevent the survival of *V. lienosa* specimens once they were introduced.

Further study and collection of additional specimens will be necessary before we can determine more precisely what factor or factors form this apparent barrier.

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ABSTRACTS OF PAPERS PRESENTED AT 1977 MEETING

ENDANGERED MOLLUSKS—ANIMALS WITH ADVOCATES

Marc J. Imlay

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Abstract

Twenty-six mollusks have been listed as Endangered Species. Fifty-seven others have been proposed. Criteria for determining status and distribution will be discussed, and also the following topics: threats, relations to ecosystem, natural rate

of extinction, natural versus man-made rates of extinction, introduction versus reintroduction, promising recovery measures, and the effect of listing on collecting.

POPULATION CHARACTERISTICS AND FOUR RESOURCE UTILIZATION OF *CONUS* IN THE GALAPAGOS ISLANDS

James Nybakken

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Abstract

The food of four species of Galapagos *Conus*—*C. nux*, *C. diadema*, *C. tiaratus*, and *C. lucidus*—is presented for the first time. Dietary preferences

are compared among sympatric species and with cognate species in the Indo-West Pacific area. Results indicate little food overlap.

FORM, FUNCTION, AND ADAPTIVE RADIATION IN SNAILS OF THE FAMILY CERITHIDAE

Richard S. Houbbrick

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Abstract

Although many examples of "form following function" may be cited among the Mollusca, most demonstrations of this biological axiom are qualitative. Rarely does one see a documented, quantitative study of the adaptation of structure to function within a specified taxon. The family Cerithiidae comprises a large group of marine snails of shallow tropical waters in which sympatric genera and

species are frequent. This group has undergone an adaptive radiation into various microhabitats. Niche partitioning is reflected in shell size, in form and structure, and in anatomical modifications of the radula and of the alimentary and reproductive tracts. The correlation of microhabitat with the physiognomy of each group can be demonstrated quantitatively.

PYRAMIDELLID SYSTEMATICS

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Abstract

The supraspecific classification of pyramidellids is based wholly on subjective estimates of overall shell similarities. This assumes that there have been no evolutionary convergences and divergences in shell

characters. These are shown to exist among five of the east North American "*Odostomia*" species. A hypothesis to explain the results is given.

TOWARD A DEFINITIVE HIGHER CLASSIFICATION OF NORTH AMERICAN UNIONACEA

George M. Davis, Samuel L.H. Fuller, and Caryl Hesterman

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Abstract

Multivariate analysis of the genetic relationships among 52 species of North American Unionacea has been completed. The data matrix involved 52 species x 21 sets of antisera, where the data elements were the percentage difference among taxa involving 10 to 12 proteins (antigens). Results of ordination, coupled with an assessment of morphological data, support the following classification: Family

Unionidae; subfamilies Margantiferinae, Anodontinae, Lampsilinae; tribes of the Lampsilinae are the Gonideini, Elliptionini, Amblemini, and Lampsilini. There is an assumption that *Unio* of Europe is divergent from North American Unionacea. It is clear that the tetragenous condition, as well as the length of breeding season, has undergone parallel evolution.

SOME CONSIDERATIONS AND IMPLICATIONS OF HOST-SPECIFICITY STUDIES OF UNIONICOLID MITE PARASITES ON THE SYSTEMATICS OF SOME GROUPS OF NORTH AMERICAN UNIONACEAN FRESH-WATER MUSSELS

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Abstract

Eastern North American (east of the Pacific drainage) anodontine mussels (Bivalvia: Unionacea: Unionidae: Anodontinae) are parasitized by a unique mite fauna (Acarina: Unionicolidae) consisting of 4 species of anodontine-specific mites: *Unionicola formosa* (Dana and Whelpley) (in 15 species of 7 genera of mussels), *U. arcuata* (Wolcott) (in 9 species of 6 genera), *U. tumida* (Wolcott) (in 7 species or 4 genera), and *U. wolcottii* (Piersig) a mite infesting the mantle and the foot in 12 species of 7 genera). The first three nominal species are exobranchial (infesting the outer surfaces of all demibranchs) mites of the nominal subgenus *Parasitotax* (Viets, 1949), where exobranchial lampsiline-specific

mites are of the nominal subgenus *Pentatax* (Thor, 1922). The anodontine-specificity and the homogenous subgeneric position of these mites as well as the marked similarities of *U. formosa* and *U. wolcottii* to those respective Palearctic anodontine-specific mites [*U. ypsilophora* (Bonz) and *U. intermedia* (Koenike)] support the recent biochemical evidence that the anodontines are a genetically discrete and ancient clade. Nine nominal general of eastern North American anodontines have been found parasitized by one or more species of these mites: *Anodonta*, *Anodontoides*, *Arcidens*, *Arkansia*, *Alasmidonta*, *Prolasmidonta*, *Strophitus*, and *Lasmigona*. The monotypic genus *Simpsoniconcha* has not been examined. Three

other nominal mite species have been reported from other specific locations inside anodontines: *U. aculeata* (Koenike) in the siphonal mantle, *U. serrata* (Wolcott) between the labial palps, and *Najadicola ingens* (Koenike) inside the water tubules of the gills. These three nominal species of mites, infesting a broader genetic spectrum of mussel hosts (both anodontines and lampsilines), may represent a more loosely coevolved unionicolid group toward the unionaceans than the exobranthial anodontine-specific mite taxa noted above; these data may also imply that the selective forces exerted by the microhabitats at the sites of infestation are not unique to any presently recognized suprageneric group of unionaceans infested by these mites. No unionicolids were found in any of the four presently recognized species of margaritiferae in North America; no unionicolids have been reported from the Palearctic margaritiferae. Although all margaritiferae in question are

generally restricted to very unique habitats, at present, insufficient data do not permit a generalization to be made regarding the absence of unionicolid parasitism in margaritiferae. A conjecture may be made that when an ancient unionicolid assemblage had begun to coevolve with an ancestral unionacean genetic stock, the margaritiferae clade may already have been genetically discrete enough to have been unamenable to a coevolution with the ancestral unionicolids. All suprageneric unionacean taxa noted above are sensu Davis and Fuller, AMU Bulletin for 1977.

The authors acknowledge the use of mussel lots from the Academy of Natural Sciences of Philadelphia, the Ohio State University Museum, and the Delaware Museum of Natural History, and financial assistance from the Department of Biology and the Graduate Student Organization at the University of Southwestern Louisiana.

REPRODUCTION OF UNIONIDAE: *ELLIPTIO* IN NORTHERN FLORIDA

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Abstract

Northern *Elliptio complanata* and *E. dilatata* brood larvae during 2-3 months, whereas Floridian *E. arcata*, *E. complanata*, and *E. icterina* contain gravid animals for 6-8 months a year. In the latter,

sex ratios can be biased by general size dimorphism between males and females; rare male-hermaphrodites are also present.

THE BIOCHEMISTRY OF HATCHING IN *BUSYCON*

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Abstract

Of the three molluscan hatching mechanisms—mechanical, osmotic, and enzymatic—neogastropods are limited to enzymatic because of the nature of their egg cases. In *Busycon*, the species-specific

enzyme exhibited proteolytic and chymotryptic activity. The plug (substrate for this enzyme) differed in amino-acide composition from the rest of the capsule.

HISTOLOGICAL AND HISTOCHEMICAL STUDIES OF THE SPERMATHECA IN *SONORELLA ODORATA* AND *SONORELLA SANTARITANA*

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Abstract

The spermatheca of pulmonate land snails has long been described as an organ for spermatophore dissolution or digestion of excess sperm. Indeed, there is much circumstantial evidence to support this contention. The present study was initiated in an attempt to gather direct histochemical evidence as to the organ's function in two species of *Sonorella*, a helminthoglyptid genus of which little is known concerning reproductive physiology.

The spermatheca in all members of the genus *Sonorella* is a spherical organ at the end of a long duct. In the species examined in the present study, *S. santaritana* and *S. odorata* from Arizona, the organ is lined with a columnar epithelium. The wall is thin overall with a diffuse layer of muscle and an outer adventitia. The contents form a compact, reddish mass in the lumen.

All individuals examined in the present study were sacrificed post-copulation. Cytochemical demonstrations using the Feulgen Reaction and PAS technique showed the contents to be mostly mucin with sperm heads in various stages of dissolution. Deoxyribonuclease, ribonuclease, and protease activity were demonstrated by the use of gel-digestion techniques using fresh, frozen tissue sections. All three enzymes were located in *S. odorata* and deoxyribonuclease was demonstrated in *S. santaritana*. Deoxyribonuclease and protease action was confined to the lumen and was most intense within the epithelial cells, probably within lysosomes, although some action was noted in the lumen.

The presence of these enzymes confirms a digestive role for the organ. Further studies are in progress to identify additional enzymatic activity.

ELECTRON MICROSCOPE INVESTIGATIONS OF THE REPRODUCTIVE SYSTEM OF *SONORELLA SANTARITANA*

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Abstract

The morphology of the wall and luminal contents of the spermatheca of *Sonorella santaritana* Pilsbry & Ferriss was investigated at the ultrastructural level. It was demonstrated that the wall of the spermatheca is divided into distinctive layers.

The layer bordering the lumen is made up of two easily differentiated cell types. One type was ciliated columnar epithelium; the other less numerous type was non-ciliated and secretory. The morphology of the ciliated columnar cells appeared to be similar to that reported for the epithelium in mammalian small intestine. The secretory cells contained innumerable vesicles and large numbers of golgi complexes. Both of these cell types terminated distally in a complex labyrinth intermeshed with a non-cellular basal layer.

The central layer of the spermathecal wall consists of muscle cells intermixed with lobed secre-

tory cells and ground substance. The secretory vesicles contained in the cells of this layer were morphologically distinct when compared to those vesicles found in the cells bordering the lumen.

The outer layer of the spermatheca is comprised of a loosely packed adventitia, the cells of which appeared to be highly vacuolated and contained few easily discernible inclusions.

There were no intact cells in the luminal contents. Rather, there was a preponderance of sperm cells and matrix material in various stages of degeneration. The material at the outer edge of the lumen was more easily recognized than that in the central core.

These results tend to support the previously proposed hypothesis that the spermatheca of selected gastropods is an organ capable of digestive and, perhaps, absorptive functions.

VISUALLY-MEDIATED ORIENTATION IN *LITTORINA IRRORATA*

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Abstract

Littorina irrorata inhabits areas of vegetation in the upper intertidal zone. It feeds on the substrate at low tide but ascends plant stems at high tide, thus avoiding predators. Experimental evidence indi-

cates that both orientation toward vegetative areas, when the animal is released on bare sand, and orientation to individual plant stems is visually mediated.

EOCENE MOLLUSCAN ZOOGEOGRAPHY AND THE ORIGIN OF THE CARIBBEAN FAUNA

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Abstract

Nine Eocene molluscan faunas were compared to the Inglis fauna (Early Jacksonian, Florida). Substrate and distance between faunas were found to control faunal similarity. Caribbean mollusks reflect

a Tethyan origin that was more obvious in the Eocene. Increased provinciality was caused by tectonic events and rapid speciation of western hemisphere endemics and Tethyan relicts.

A TROPICAL MARINE MOLLUSCAN ASSEMBLAGE
IN THE NORTHEASTERN GULF OF MEXICO

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Abstract

Two hundred and fifty-one molluscan species, including 179 gastropods, 63 bivalves, 8 polyplacophorans, and one scaphopod, are reported from the Florida Middle Ground, an offshore reef in the northeastern Gulf of Mexico. Specimens were collected as epizooics on corals, among fouling organisms, and among biogenic sediments in three samples from the reef. Sixty-four percent of the gastropod species belong to nine families of typically small taxa ("micromollusks"), including Rissoinidae (9), Vitrinellidae (16), Caecidae (8), Cerithiidae (excluding *Cerithium* but including Cerithiopsinae; 24), Triphoridae (17), Melanellidae (8), Turridae (9), and Pyramidellidae (24). Common or significant gastropods characterizing the fauna include *Calliostoma barbouri*, *Astraea tecta*, *Rissoina aberrans*, *Rissoina fischeri*, *Caecum pulchellum*, *Cerithium litteratum*, *Cerithiopsis taeniolata*, *Triphora turristhormae*, *Muricopsis oxytatus*, *Pisania karinae*, *Leucozonia nassa*, *Odostomia didyma*, and *Turbonilla pupoides*. All polyplacophorans except *Ischnochiton papillosus* are tropically re-

stricted species; *Toncia schrammi* and *Stenoplax floridana* were most common. Bivalves are primarily represented by reef-dwelling epizooics or borers (e.g., Arcidae, Mytilidae, Spondylus), supplemented by sponge dwellers and small species adapted for living among coarse sediments. Characteristic species include *Arca imbricata*, *Barbatia*, *Barbatia cancellaria*, *B. domingensis*, *Gregariella coralliophaga*, *Iso-gnomon radiatus*, *Malleus candeanus*, *Spondylus americanus*, *Aligena* cf. *texasiana*, *Carditopsis smithi*, and *Crassinella martinicensis*. Brief, previously published lists of larger, selectively collected mollusks from Florida Middle Ground, and from West Flower Garden Bank, off the Texas coast, are not sufficiently similar in numbers of species or in collecting techniques to allow extensive comparisons, but larger, more common species from these studies and ours are similar. Many Florida Middle Ground mollusks occur offshore of the Carolinas and at Bermuda. Nearly all species are common elements of shallow-

water communities in the Florida Keys, Bahamas, and Caribbean. This northeastern Gulf assemblage, distinctly tropical in affinity, should be regarded as a reduced or diminished extension of the tropical

Caribbean fauna rather than a portion of a separate Gulf of Mexico molluscan zoogeographic province as has recently been proposed.

SPERMATOGENESIS AND OOGENESIS IN *TAREBIA GRANIFERA* (GASTROPODA: MELANIIDAE)

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Robert V. Blystone and Harold D. Murray

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Abstract

Tarebia granifera (Lamarck) is widely reported in the literature as parthenogenetic. In 13 years of examining thousands of *T. granifera* in our laboratories using light microscopy, there has been no evidence of sperm cells. Jacob (Trans. Roy. Soc. Edin., Vol. LXIII, Part II, 1956-57) used cytological procedures to determine that a population of *Melanoides tuberculata* contained 3% males. Jacob also reported seeing spermatogenesis in *M. tuberculata* but did not support this claim. *M. tuberculata* is a close relative of *T. granifera*.

Mr. Ron Scates, graduate student, was routinely examining the ultrastructure of the hepatopancreas (digestive gland) of *T. granifera* on a Hitachi HS-8 electron microscope when he accidentally photographed what appeared to be sperm tails. Additional electron microscopic work by Mr. Scates showed the complete process of spermatogenesis in *T. granifera*. In addition to numerous mature sperm, Mr. Scates photographed seminiferous

tubules, primary spermatocytes, secondary spermatocytes, acrosome formation, middle piece formation from the nebenkern, and flagellar formation. All observations were from snails less than 10mm in shell length.

Mr. Michael Matthes, graduate student, has recorded the ultrastructural changes occurring in oogenesis in *T. granifera*. Previtellogenic cells, early and late vitellogenic cells, and mature oocytes were photographed. All snails used by Mr. Matthes were greater than 10mm shell length, and no spermatogenesis was observed.

Fertilization of an oocyte of *T. granifera* has not been observed, and no proposal is made here as to the fate, if any, of these sperm. Ultrastructural studies are continuing on the uninfected hepatopancreas and the hepatopancreas infected with rediae of *Philophthalmus gralli*. Snails for these studies are 10mm or greater in shell length, and spermatogenesis has not been observed.

HISTOLOGICAL AND ULTRASTRUCTURAL STUDIES OF *TAREBIA GRANIFERA* (GASTROPODA) HEPATOPANCREAS PARASITIZED BY *PHILOPHTHALMUS GRALLI* (TREMATODA)

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Abstract

The effects of *Philophthalmus gralli* rediae on the hepatopancreas of *Tarebia granifera* are examined histologically and ultrastructurally. The hepatopancreas is a simple branched tubular gland surrounded by a tunica propria and is connected to the stomach by a single duct. The gland tubules are supported by a connective tissue network and each consists primarily of digestive and secretory cells. The columnar digestive cells possess a brush border, pinocytotic vesicles, large vacuoles, scant membranous elements, few mitochondria and a basally positioned nucleus. The cylindrical

secretory cells also have a basally positioned nucleus, but contain extensive rough endoplasmic reticulum-Golgi complexes, numerous dense mitochondria, and few vacuoles.

P. gralli infection causes disruption of the normal organization of the hepatopancreas. There is a reduction of host tissue mass of which some may be due to ingestion by the rediae. Pressure exerted by growing rediae mechanically compresses tubules reducing lumen diameters. Radial absorption of nutrients, plus the release of metabolites and extracorporeal digestive enzymes cause host cells autoly-

sis resulting in increased vacuolization, as reflected by changed staining characteristics.

Three additional phenomena involve proliferation of hepatopancreatic connective tissue elements. The number of vesicular connective tissue cells increases, perhaps in response to glucose uptake by the rediae. Cells with extensively de-

veloped endoplasmic reticulum, dense mitochondria, and a fenestrated cell membrane are present but their origin and function are not known. Amoebocytes, smooth muscle cells, and collagen-like extracellular fibers form a layer surrounding, and often in contact with, the redial wall.

OBSERVATIONS ON BROOD PRODUCTION IN THREE VIVIPARID GASTROPODS

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Information on brood production in 3 southeastern viviparids [*Campeloma geniculum* (Conrad), *Lioplax pilsbryi* Walker, *Viviparus georgianus* (Lea)] was obtained from the monthly analysis of incubating broods for 1 year. Each species displays a seasonal pattern of development of a single brood per year. Both fertilizations and births occur over a period of several months. Initial fertilizations produce broods of only small young, and continued fertilizations in the same adult produce broods with the young in a size series. As the older young from the initial fertilizations are born, broods of only large young from the more recent fertilizations occur. In some cases, new fertilizations occur before all births of the former brood are con-

cluded resulting in the simultaneous incubation of 2 different broods.

The number of young per brood varies seasonally in each species. Maximum brood size occurs during late summer with the young in a size series. The number of young per brood is positively correlated to parental size in *C. geniculum* but not *L. pilsbryi* or *V. georgianus*.

Comparison of brood production in various populations of each species shows the same seasonal patterns of brood development. However, the number of young per brood and the diameter of the young at birth is highly variable even when parental sizes are nearly identical.

OVIPOSITION OF *POMACEA PALUDOSA* (SAY) IN LAKE OKEECHOBEE, FLORIDA

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Reproductive rates of *Pomacea paludosa* (Say) were studied monthly from January, 1976 through June, 1977 in Lake Okeechobee, Glades County, Florida. The area investigated, known locally as the Monkey Box, is a shallow backwater bay in the southwest corner of the lake, seven miles northeast of Moore Haven.

Monthly estimates of reproductive rates were determined by counting all unhatched egg clutches in one-twentieth acre transects (165.8 meters by 1.22 meters). Transects were placed in major vegetation stands around the bay. Two transects (*Typha domingensis*, *Eleocharis cellulosa*) were monitored in 1976 with four additional replicates (*Typha*, *Eleocharis* (2), *Pontederia lanceolata*) sampled in 1977.

Numerical abundance of clutches increased from

initiation of oviposition in February, 1976 to June, 1976 (2.5 clutches/m²) and then decreased until cessation in November. Oviposition resumed the following March, peaked in May (2.3 clutches/m²), and declined in June. Maximum densities of a single replicate was 4.5 clutches/m² in June, 1976, and 6.2 clutches/m² in May, 1977. Mean monthly densities for the reproductive season were .88 clutches/m² (8800 clutches/ha) for 1976 and 1.55 clutches/m² (15,500 clutches/ha) for 1977. Oviposition in transects of *Typha* was found to be significantly higher ($P < 0.05$) than in those of *Pontederia* or *Eleocharis*.

Monthly estimates of clutch size were determined by counting the number of eggs per clutch of clutches selected randomly from four vegetational

types (*Pontederia*, *Eleocharis*, *Typha*, *Sagittaria lancifolia*). Mean clutch size ($N=748$) was 26.7 ± 10.9 eggs per clutch. The maximum clutch size recorded was 141 eggs in March, 1977. Clutches on *Pontederia* and *Typha* were found to have significantly larger ($P < 0.05$) numbers of eggs ($\bar{X} = 29.2$ and 30.7 , respectively) than either *Sagittaria* ($\bar{X} = 27.7$) or *Eleocharis* ($\bar{X} = 22.3$). Mean egg diameter was $4.4 \pm .3$ mm and exhibited no correlation to clutch size ($r = .13$, $P > 0.3$).

Hatching occurs in 18-22 days in the field and in 22-28 days in the laboratory. Preliminary data indicates a hatch rate of approximately 70% at 27°C.

A conservative estimation of production for the nine month reproductive cycle at 1.5 million snails per hectare during 1976 and 1.2 million snails per hectare for the period March-June of 1977.

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CORAL REEF MOLLUSCS OF THE SOUTHWESTERN GULF OF MEXICO

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Abstract

The Mollusca of Lobos Reef (21°28' N, 97°13' W) 100 km south-southeast of Tampico, Mexico, and Enmedio Reef (19°06' N, 95°56' W) 15 km southeast of Vera Cruz, where studies during late May and June 1973. Two hundred and ninety species (178 alive) were collected, consisting of 211 Gastropoda, 73 Bivalvia, 4 Polyplacophora, and 2 Cephalopoda. Two hundred and twenty species (127 alive) were collected on Lobos and 219 (131 alive) on Enmedio. Wading, snorkeling and SCUBA were employed as collecting techniques in successively deeper water above the reefs. Random observation was used for the large motile and attached species, bottom samples were analyzed for micromolluscs, and rock samples were examined for boring species.

The ecological distribution of mollusks within each of the reef biotic zones was studied in detail. The supratidal rocky shore habitat had the lowest species diversity (7 gastropods) and the highest percentage of species restricted to any one zone

(100%). The *Thalassia* bed had the highest diversity (178 species), as well as the largest number of species restricted to one zone (61 species). Subtidal, hard substrate species extended through more of the reef biotic zones than most supratidal and intertidal, hard substrate species or subtidal, soft substrate species.

Of 245 species from Lobos and Enmedio reefs 97-98% were tropical species. Most of them were wide-ranging eurythermic tropical species. Of the 245 species analyzed 143 (58%) extend to Brasil; 119 (49%) to Bermuda; 98 (40%) range into warm temperate waters; 52 (21%) extend to the offshore reef and hard banks in the northwestern Gulf; 22 (9%) range to offshore North and South Carolina and 17 (7%) extend to waters outside the western Atlantic. Twenty species (8%) were restricted to the Caribbean Province proper (excluding the above extremes), and 5 (2%) are apparently new species, possibly endemic to the southwestern Gulf reefs.

UNIONACEAN BIVALVES (PAST AND PRESENT) OF HOMINY CREEK, OSAGE COUNTY, OKLAHOMA

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Abstract

Analysis was made of unionacean bivalve shells recovered in archaeological excavations from two rock shelters along Hominy Creek, Osage County, Oklahoma. Comparisons were made with the present unionacean fauna of Hominy and nearby creeks. A total of 377 valves were recovered. These

were allocated to eleven species: *Amblema plicata* (Say), *Fusconaia flava* (Rafinesque), *Quadrula pustulosa* (Lea), *Tritogonia verrucosa* (Rafinesque), *Lasmigona complanata* (Barnes)*, *Strophitus undulatus* (Say), *Lampsilis ovata* (Say), *Lampsilis radiata* (Gmelin), *Lampsilis rafinesqueana* Frierson,

Lampsilis teres (Rafinesque)*, and *Ligumina subrostrata* (Say)*.

Radiocarbon determinations from the deposits ranged from ca. 330 to ca. 1200 A.D. Species diversity was greatest from 800 to 1100 A.D. *Amblema plicata* was dominant species at all levels. Of the eleven archaeological species recovered, only three (indicated by asterisks, above) were found still to inhabit Hominy Creek. Six additional species, not taken archaeologically, were found living in the creek: *Uniomerus tetralasmus* (Say), *Anodonta imbecillis* Say, *Carunculina parva* (Barnes), *Leptodea*

fragilis (Rafinesque), *Proptera laevis* (Lea), and *Truncilla donaciformis* (Lea).

Species that form a prominent part of the fauna of the middle part of some nearby streams and which occur in the archaeological deposits have disappeared from Hominy Creek. Factors possibly related to this disappearance may be: (1) pollution related to petroleum production, (2) increased entrenchment, siltation and turbidity of the stream and (3) intermittency. Much of Hominy Creek is scheduled to be inundated by Skiatook Reservoir in the early 1980's.

NOTES ON THE GENUS *VILLOSA*

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Abstract

The freshwater genus *Villosa* belongs to the family Ambilemidae, subfamily Lampsilinae. Female reproductive characters separate it from *Lampsilis*. Primarily an Atlantic genus, it includes

species from the Eastern Gulf Coastal rivers, both sides of Florida, and then northward as far as the Tar River of North Carolina.

The American Malacological Union and the Systematics Association Symposium THE EVOLUTION AND ADAPTIVE RADIATION OF MOLLUSCA MODERATOR: George M. Davis

CONTRASTING VIEWS IN PRESENT-DAY LITERATURE OF PHYLOGENY OF THE EARLY MOLLUSKS

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Discussant: Robert M. Linsley (AMU)

Abstract

Currently, two fundamentally different patterns have been proposed to describe the early evolution of the Mollusca; both use many of the same observations but interpret them differently.

Runnegar and Pojeta have suggested that all classes of mollusks persist back into the early Paleozoic (Cambrian and Ordovician); Gastropoda, Pelecypoda, and Monoplacophora first appeared in

the Early Cambrian. The extant classes plus the extinct class Rostroconcha (Early Cambrian to Permian) constitute all the diversity at the class level, in their view. In contrast, Yochelson believes that several extinct groups of mollusks deserve class ranks. Most appear early in the fossil record and predate the first known occurrences of representatives of extant classes.

Major areas of disagreement involve: placement of Hyolitha as a molluscan class or as a separate phylum; distinction of fossil mollusks from "worm" tubes; definition of the class Monoplacophora; assignment of Early Cambrian fossils to Gastropoda and Pelecypoda; and disposition of Stenothecoidea and Matheva, judged by Yochelson to be classes and by Runnegar and Pojeta not to be classes.

Relationships of high-level taxa, orders, classes,

and phyla should be approached with caution. The store of facts is small, whereas the inferences drawn are large. Nevertheless, the pattern of early molluscan evolution proposed by Yochelson would appear—to Yochelson, at least—to be more generally similar to the pattern of adaptive radiation (seemingly a basic evolutionary phenomenon at all systematic levels) than is the more linear pattern proposed by Runnegar and Pojeta.

SHELL FORM AND RATES OF LOCOMOTION IN GASTROPODS

Robert M. Linsley

Colgate University, Hamilton, New York (AMU)

Discussant: Ellis L. Yochelson (AMU)

Abstract

Rate of locomotion in Gastropoda correlates surprisingly well with the shape of the shell of the snail. In general, the fastest snails hold their shells in such a way that the frontal cross-section area is very small, the center of gravity and pressure point are very low, there is little or no torque, and essentially no surface ornamentation. If any of these factors is increased, the net results is a more slowly moving snail. The slowest snails maximize at least one of the parameters (i.e., extremes in ornamentation, very high center of gravity, etc.) and commonly achieve high values in more than one (i.e., snails with high torque also have a high center of gravity

and a large frontal cross-sectional area). The very slowest gastropods are the "shell-draggers," those who drag their shell across the substrate rather than balancing it over the cephalopodal mass.

Unlike most other organisms, the size of the organism does not seem to be a major determinant of speed. Possibly this is because "stride" is of less significance in the locomotion of gastropods. It is presumed that the stromboids would exhibit considerable correlation between size and speed. Ciliary movers show the least correlation between size and speed.

WHY IS A SNAIL THAT HIGH AND THAT WIDE?

Arthur J. Cain

Department of Zoology, University of Liverpool, Liverpool, England; Systematics Association (SA)

Discussant: James J. Murray (AMU)

Abstract

Surprising regularities have been found in the height and breadth of shells of a fauna taken together. In different parts of the world, different taxonomic groups combine to make up characteristic distributions (Cain, 1977). In land pulmonates,

the characteristic distribution is of two wedges. It has now been shown that the same distribution is found in land operculates, with one major exception in Africa and Madagascar.

EVOLUTION AND ADAPTIVE RADIATION OF *CERION*: A REMARKABLY DIVERSE GROUP OF WEST INDIAN LAND SNAILS

David S. Woodruff

Department of Biological Sciences, Purdue University, West Lafayette, Indiana (AMU)

Discussant: G.S. Oxford (SA)

Abstract

The pulmonates of the genus *Cerion* are remarkable for the extreme variability of their shells. The vast array of shell types present in Cuba and the Bahamas, coupled with past typological taxonomic practices, has resulted in the naming of over 600 "species." The complex patterns of geographic variation are so confusing that several workers have despaired of the possibility of ever applying the biological species concept to this group. The allegedly haphazard distribution of fossil and living shell types has been attributed to the vagaries of hurricane dispersal.

Stephen Jay Gould, of Harvard University, and I have been collaborating on a holistic study of the geographic variation, ecology, and evolution of these remarkable shells. We have begun to make sense of this extraordinary situation by detailed mapping of geographic variation in the field and by laboratory studies of multivariate morphometrics and biochemical genetics. So far we have found that the 200 "species" of the northern Bahamas reduce to a single pair of contrasting morphotypes: phenetic and genetic variation is continuous rather than capricious. Furthermore, while hurricanes may have played a role in establishing some distribution patterns, their importance appears to have been overestimated. In the northern Bahamas, we can discern an overall biogeographic pattern that appears to have evolved *in situ* during the late Cenozoic. As a result of these studies and others involving *Cerion* from elsewhere in the Bahamas, Cuba, Hispaniola, Puerto Rico, the Dutch Leeward Islands, and the Florida Keys, we anticipate a

downward revision of close to two orders of magnitude in the number of valid species.

Despite the enormous taxonomic literature on *Cerion*, we know remarkably little about their natural history or the adaptive significance of the variation in shell morphology. It was widely held that the snails are obligate halophiles, that they are restricted to a zone close to the shore, and that their abundance (up to 212 per square meter) stems from a lack of predation. Field observation over the last few years has shown that these beliefs are unfounded. Long-term ecological studies in the northern Bahamas have been initiated in an attempt to generate some basic information on population size, dispersion, dispersal, growth rates, predation, and mortality. The activities of over 1,500 individually marked snails have been followed periodically since November, 1973. Laboratory studies on the mechanical strength and thermal properties of the different shell types are also being conducted to try to establish the adaptive significance of the observed morphological variation. The results of these studies will be presented, and, in addition, attention will be drawn to a number of other outstanding problems (including *Cerion*'s ability to estivate for protracted periods) presented by these animals.

In a broader context, *Cerion* will be shown to display one of nature's most impressive displays of morphological variety. While this diversity has been acquired without widespread speciation or extensive genetic differentiation, the group provides prime material for studies of the genesis and maintenance of morphological complexity.

CHANGES OF GENE FREQUENCY IN *CEPAEA NEMORALIS*: A FIFTY-YEAR RECORD

James Murray

Department of Biology, University of Virginia, Charlottesville, Virginia (AMU)

and

Bryan Clarke

Department of Genetics, University Park, Nottingham, England (SA)

Discussant: Arthur J. Cain (SA)

Abstract

Populations of the land snail *Cepaea nemoralis* inhabiting the coastal sand dunes at Berrow,

Somerset, England, have been under observation since 1926. The original survey was carried out by

Professor A.E. Boycott and Captain Cyril Diver, who not only collected an extensive series of samples but also produced a careful map of their localities. Thus it is possible for us to make direct comparisons with samples taken in 1959-60, 1963, 1969, and 1975.

Clinal patterns in the distribution of morph frequencies have remained essentially the same over the fifty-year period. However, there have been overall changes in the frequencies of two of the principal morphs. The allele for brown shell color (C^B) has shown a decrease in frequency, while the allele for a single central band (U^3) has shown an overall increase. The direction and consistency of these changes have been investigated by the use of

the G statistic and the analysis of covariance. These methods show clearly that there are differences in the frequency of both morphs among the localities and over the years. Despite one locality that shows an increase in brown, there is a consistent overall decrease in this morph, representing a mean selective disadvantage of about 3% per generation. With respect to the midbanded form, analysis of covariance indicates that there are real differences among localities in the direction or the amount of change. If we nevertheless calculate the mean selective advantage of this morph, we find it to be about 4% per generation. These differences can be interpreted in terms of changes in the habitats where the snails are found.

THE NATURE AND DISTRIBUTION OF FOOD-INDUCED ESTERASES IN HELICID SNAILS

G.S. Oxford

Department of Biology, University of York, Heslington, York, England (SA)

Discussant: David S. Woodruff (AMU)

Abstract

In laboratory cultures of the snail *Cepaea nemoralis*, esterase enzymes, derived from the hepatopancreas, which migrate most cathodally in acrylamide gels during electrophoresis have been shown to be coded for by six alleles at locus *Es. 1*. The alleles fall into two series, each of three alleles. Within a series there is a constant charge difference between the allelic zones, but the two series are displaced slightly relative to one another. Snails fed on foods other than carrots and lettuce, and particularly those fed on nettle (*Urtica dioica*), show induced (secondary) esterases which are post-transcriptional modifications of the genetically determined enzymes. These modifications are well defined, and in some cases secondary esterases are indistinguishable from the primary products of other alleles at locus *Es. 1*. Some individuals from all colonies so far examined have contained secondary esterase zones.

The biochemical differences between primary and secondary esterases are not known. At least three (and possibly five) changeable sites on the esterase molecule must be postulated to explain the mobility differences between the two series of alleles and between primary and secondary zones. Attempts to simulate these differences with chemicals known to modify particular molecular features have met with only limited success. Formaldehyde and glyceraldehyde (but not acetaldehyde) increase the mobility of primary and secondary

esterases by exactly two units. Formaldehyde is known, among other things, to block the γ -group of lysine, but this does not appear to be the case here, since electrophoresis at pH 10.2, the pK_a of lysine, yielded identical esterase patterns. Iodoacetamide treatment resulted in a reduction in the electrophoretic mobility of zones by about 25% of the unit distance between them. This reduction is too small to mimic the electrophoretic shift between the two series of alleles.

The occurrence of food-induced esterases has been sought in five other species of helicid snails (*Cepaea hortensis*, *Helix aspersa*, *Monacha cantiana*, *Arianta arbustorum*, *Hygromia striolata*). Only one, the closely related *Cepaea hortensis*, showed evidence for secondary esterases. The pattern of modification is precisely the same as in *C. nemoralis* and is much easier to study since only one allele (*Es. 1'*) is present.

The causal relationship between the ingestion of nettle and the production of secondary esterases is obscure. The conversion of primary to secondary esterase is much faster than the reverse reaction, whereby secondary esterases are gradually lost. This would argue against an hypothesis involving the induction in the snail of a second locus which produces a modifier substance. It is suggested that the ingestion of nettle may powerfully select for a bacterial component of the snail's gut flora which is capable of modifying esterases produced by locus

Es. 1. A diet of carrot and lettuce would impose mild selection against this bacterial component, leading

to its gradual reduction in numbers over a long period of time.

REPRODUCTION AND ITS CONTROL IN THE SLUG *AGRIOLIMAX (DEROCERAS) RETICULATUS*

Norman W. Runham

Zoology Department, University College of North Wales, Bangor, Gwynedd, United Kingdom (SA)

Discussant: Peter Calow (SA)

Abstract

As with other stylommatophoran pulmonates, *Agriolimax reticulatus* is a simultaneous hermaphrodite. For most of its life, both developing sperm and oocytes are apparently intermingled within the gonad. However, after a short, undifferentiated period, the male elements in the gonad multiply and mature first. While some oocytes arise during this period, the majority of oocytes arise, and all mature, after the male phase. As with the development of the gonad, the male accessory sex organs mature first, to be followed, during the female phase, by the maturation of the female organs. Courtship and copulatory behavior is first shown by half-grown animals in the male phase and egg-laying behavior by the larger animals, which are in the female phase. There is, however, considerable variation in the degree of overlap of the developmental stages and types of behavior in this species.

There is now clear evidence that this complex maturation sequence and all the varied functions of the reproductive system are under hormonal and nervous control. Firstly, somatic growth is controlled by secretions from the medial neurosecretory cells located in the cerebral ganglia. The existence of hormonal control of the male accessory glands can readily be demonstrated, but the source of the hormone is at present unknown. Control of the female accessory gland maturation, together with vitellogenesis in the oocytes, is controlled by secretions of the dorsal bodies, endocrine organs attached to the cerebral commissure. Evidence for the control of gametogenesis will be discussed, together with evidence for hormonal relationships between the gonad and reproductive tract.

THE EVOLUTION OF LIFE-CYCLE STRATEGIES IN FRESHWATER GASTROPODS

Peter Calow

Department of Zoology, University of Glasgow, Glasgow, Scotland (SA)

Discussant: K. Elaine Hoagland (AMU)

Abstract

From a review of available data, I will examine the adaptive significance of differences in two aspects of the life cycles of freshwater gastropods: (a) the "choice" between semelparity and iteroparity, and (b) the "choice" between egg size and egg numbers.

Most temperate, freshwater gastropods are annual and semelparous. On the other hand, marine and terrestrial species tend, in general, to be perennial and iteroparous. Since freshwater species must have evolved from marine, and possibly terrestrial, ancestors, Cole's classical question, "Why should semelparous species evolve into iteroparous species?" is reserved for the gastropods. I will argue that here the semelparous state is associated with reproductive "recklessness" on the part of the parent and that the latter has evolved in response to

the more intense, density-independent selection associated with freshwater habitats.

As gastropods have invaded freshwater, there has been a well-documented trend toward larger-sized eggs, telescoping of developmental stages into the egg, and thus to larger, more fully developed hatchlings. Again, these adaptations can be explained as a response to the challenge posed by inclement conditions. Some freshwater gastropods produce larger eggs than others, and these differences can be correlated with differences in ecology. However, since the number of progeny that ultimately reaches maturity depends both on the fitness of individual progeny and on their initial density, different strategies, in terms of the choice between egg size and numbers, can feasibly lead to equivalence in parental fitness under the same eco-

logical conditions. This principle, of alternate, equi-fit adaptations to the same environmental

challenge, will be illustrated by reference to littoral species.

THE EVOLUTION OF PROTANDRY AND LABILE SEX DETERMINATION IN THE MOLLUSCA

K. Elaine Hoagland

Department of Biology, Lehigh University, Bethlehem, Pennsylvania;
Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania (AMU)
Discussant: Norman W. Runham (SA)

Abstract

Many mollusks in several taxonomic groups (Mesogastropoda, Bivalvia) and several ecological settings (parasites, filter-feeders, wood-borers) are protandrous hermaphrodites, with varying degrees of environmental determination of sex. I delineate the selective forces that have led to the establishment of protandry and labile sex determination in some, but not all, mollusks. I first report on a series of experiments on the sexual behavior and sex determination of four species in the mesogastropod genus *Crepidula*, and correlate differences I find with differences in the reproductive patterns of these species. I review the literature on protandry and labile sex determination in mollusks and some other invertebrates in order to test the generality of the conclusions generated from the study of *Crepidula*.

Species of *Crepidula* with planktonic larval development and that are rarely substrate-limited exhibit labile sex determination and have socially influenced sex ratios. Their gregarious behavior and female-induced delay of sex change appear to be mediated by pheromones, possibly through a common mechanism. Species of *Crepidula* lacking planktonic larvae also lack gregarious behavior, and sex change and sex ratio are independent of influence by other members of the species. Therefore, species patterns in control of sex change appear to be correlated with the mode of larval devel-

opment and dispersal, and with substrate constraints.

Protandry is advantageous—that is, it increases individual fitness—when one sex increases in fertility with age and size faster than the other. This is true in many mollusks where female fecundity is related to large body size, but male fecundity is related to mobility and therefore often to small size. Labile sex change that is influenced by the environment optimizes the size and age at sex change in protandrous species, thus maximizing individual fitness. This is important in species for which the optimal age at sex change varies from place to place and from generation to generation. Sedentary species with planktonic larvae fall into this category. Gregariousness, in addition to protandry and labile sex change, ensures that each individual will reproduce. An isolated individual becomes female immediately upon metamorphosis and attracts spat, which become male, providing a mate. The advantage to colonizing populations of sedentary species is that every encounter between individuals is potentially productive of offspring. Mollusks that are largely sedentary as adults but possess dispersal stages and have substrates patchy in time and space have evolved protandry: the Calyptraeidae, oysters, wood-boring bivalves, and the parasitic mesogastropods are outstanding examples.

MINI-SYMPOSIUM: MOLLUSCA OF THE WEST INDIES

Chaired by: Richard S. Houbrick, Division of Mollusks, National Museum of Natural History, Washington, DC

INTRODUCTION

Richard S. Houbrick

ZOOGEOGRAPHY OF THE WEST INDIES

R. Tucker Abbott, Delaware Museum of Natural History, Greenville, Delaware

OPISTHOBRANCHS OF THE WEST INDIES

Germaine L. Warmke, Gainesville, Florida

LIVING ANIMALS OF SELECTED WEST INDIAN MOLLUSCA

Robert Robertson, Department of Malacology, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania

SOME LOOK-ALIKE TURRIDS OF THE CARIBBEAN

Virginia Orr Maes, Department of Malacology, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania

CERITHIDAE OF THE CARIBBEAN

Richard S. Houbrick, Division of Mollusks, National Museum of Natural History, Washington, DC

SELECTED CONES OF THE WEST INDIES

William E. Old, Jr., Department of Mollusks, American Museum of Natural History, New York, New York

WEST INDIAN MOLLUSKS IN FLORIDA

William G. Lyons, Florida Department of Natural Resources, Marine Laboratory, St. Petersburg, Florida

SMALLEST MARINE MOLLUSKS IN THE CARIBBEAN

Donald R. Moore, Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, Florida

INFORMAL WORKSHOP — DISCUSSION — IDENTIFICATIONS OF WEST INDIAN MOLLUSCA

AMU ANNUAL REPORTS

AMU ANNUAL BUSINESS MEETING, JULY 15, 1977, NAPLES, FLORIDA

The business meeting of the Forty-Third Annual Session of the American Malacological Union was called to order at 2 p.m. by President George M. Davis in the Sunset Terrace Room of the Beach Club Hotel at Naples, Florida.

Minutes from the Forty-Second Annual Meeting held at Columbus, Ohio, were APPROVED as printed in the 1976 Bulletin.

Recording Secretary Constance E. Boone gave a summary of membership in the fiscal year of 1976 and the first half of 1977. She announced that 10 new members had been added at the current meeting. Summary APPROVED. (Full report printed below.)

A summary of the report from Corresponding Paul R. Jennewein was presented by the Recording Secretary. Summary APPROVED. (Full report published below.)

Dr. Harold Murray summarized the important transactions in Treasurer Myra L. Taylor's report. Summary APPROVED. (Full report printed below.)

Dr. Murray reported that the auditing committee testified by signing the Treasurer's report that the books were in perfect order.

Dr. Murray presented the proposed budget for 1978 as follows:

INCOME	PROPOSED BUDGET
Memberships	\$5,900.00
All types except life members	
Sales	
HTSCS	500.00
Rare & Endangered	10.00
Bulletin, Back issues	150.00
Teskey Index	150.00
Page Charges to Authors	700.00
Proceeds, Meeting of year ended	150.00
Donations	50.00
Miscellaneous	30.00
TOTAL	\$7,640.00

DISBURSEMENTS

Bulletin	\$4,200.00
Newsletter	1,000.00
Conservation Committee	200.00
Membership Committee	25.00

President's Fund	50.00
California Filing	5.00
Officers to Meetings	700.00
Legal Defense	50.00
Postage (except Bulletin & Newsletter)	280.00
Office Supplies	100.00
Postal Permit	40.00
Miscellaneous	120.00
Annual Meeting Expense	150.00
Nautilus, adv.	20.00
Adv. HTSCS	300.00
Editor's Expense	200.00
TOTAL	\$7,740.00

\$-100.00 (deficit)

Dr. Davis explained the deficit amount budgeted by reporting that Council had approved an additional sum for conservation activities and funds for advertising publications.

Budget APPROVED.

Dr. Carol Stein gave a resume of activities of the Conservation Committee. It included a listing of the major items handled, such as a letter from AMU sent opposing the Florida barge canal, a letter to the Office of Endangered Species on possible changes in the rule making on endangered species listings, letters sent on shells on the International Endangered Species List where AMU went on record opposing the blanket listing of taxa. Dr. Stein brought members up to date on action on the Big Darby Creek case which has now been referred to the Ohio State Supreme Court. If the decision is made to review, then AMU will file another Amicus Curiae brief at a cost of an additional \$50.00. Dr. Stein asked members to get in touch with her if they wished AMU to take action on particular conservation matters, stating that she required dossiers and data to help decide possible action by AMU. She also announced that testimony is being prepared for the Senate committee on possible revision of the Endangered Species Act of 1973. She announced that Dr. David Stansbery would be a delegate at the hearing and that he would represent AMU also. She expressed concern on habitat protection and the need to simplify red tape on scientific collection of mollusks. She reported also that AMU would draft a letter to the Office of Endangered Species recommending and urging

that one or more malacologists be on the staff of OES. Report APPROVED.

Dr. Davis told members that his plan last year to set up the Conservation Committee with a Council member working with the appointed Committee Chairman and other appointed members does indeed work and speeds up the process of handling matters between meetings and simplifies the matters that need to be brought to the meeting. He also stated that he had acted on one-half of the resolutions, adopted at the meeting last year, requiring that he write letters, not being able to complete required action because he did not receive dossiers, addresses, etc., on the remaining resolutions as had been expressly required by a motion adopted at last year's general meeting.

It was announced that materials continue to be accumulated, under Dr. Bill Clench's supervision as Archives Chairman, for AMU Archives.

A summation of the report from Editor Dolores Dundee on AMU publications was given by the Recording Secretary who stated that the full report will be filed. Dr. Dundee's report stated that \$4200.00 had been budgeted for the 1976 Bulletin, with actual total cost, including typesetting, printing and mailing, for 1200 copies being \$2982.06. Of the \$500.00 budgeted for the 1976 Fall Newsletter, total cost for 850 copies was \$400.66. Of the \$500.00 budgeted for the 1977 Spring Newsletter, total cost for 700 copies was \$297.46. Total cost for printing the 500 copies of the Index to the Bulletin, approved by Council but not budgeted, was \$1894.82.

Summary APPROVED.

Dr. Donald Moore presented the nominations for officers to be elected at this meeting as follows:

President—Carol B. Stein

President-elect—William E. Old

Vice-President—Clyde F.E. Roper

Corresponding Secretary—Paul R. Jennewein

Councillor-at-large—Louise Kraemer and Harold Lewis to 1979.

APPROVED by Acclamation.

Dr. Davis announced that the site for the annual meeting in 1978 would be at Wilmington, North Carolina, and that the 1979 meeting would be held at Corpus Christi, Texas, with the date to be announced later in the year.

Resolutions brought from Council and ACCEPTED by members are as follows:

1. Resolution that the AMU go on record against

which contains a listing of members, may be offered for the subscription price of \$10.00.

2. Resolution to eliminate the word "mandatory" in page charges in billing for papers printed in the Bulletin.

3. Resolution to continue the member and address listing in the Bulletin.

4. Resolution that all abstracts, as printed in the program, of papers given at the annual meeting will be published in the Bulletin without cost to the authors. A discussion clarified that these abstracts conform with the word limit imposed with the Call for Papers, and corrections of errors in the printed abstract in the program must be made with the Editor in the time limit for receipt of material as announced.

5. Resolution: In cases of papers submitted to the Bulletin, upon acceptance by the Editor, authors of said papers will be charged for page cost with the understanding that the authors will pay according to their ability to provide funds from a) institutional support, b) grant support, or c) personal funds.

6. Resolution that the 1977 meeting Symposium papers on the Evolution and Adaptive Radiation of Mollusca will be published in the Bulletin as they appear in the program.

7. Resolution to revise a By-Law as follows:

Article I Section 3 b) now reads: "Corresponding Membership: Current Regular Membership dues plus \$1.50 to cover the additional service costs of mailing."

Revision proposed to read: "Corresponding Membership: Current Regular Membership dues plus postage to be set by the Publications Committee and the Treasurer."

Purpose of change: To eliminate a fixed fee of postage in view of rising costs in foreign mailing. Corresponding members are those outside the Western Hemisphere.

8. Resolution to send night telegrams with greetings from this annual meeting to Honorary Life President S. Stillman Berry and to Honorary Life Members not in attendance.

Dr. Davis's call for any other business to be brought before the meeting met with no response.

Meeting was adjourned at 2:30 p.m.

Respectfully submitted,
Constance E. Boone,
Recording Secretary

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING DECEMBER 31, 1976.

CHECK BOOK BALANCE, JANUARY 1, 1976

RECEIPTS:

Memberships: Regular	4657.00		
Life	94.33		
Corresponding	157.09		
Clubs and Institutions	932.00		
Subscribing	84.00	5924.42	
Sales: HOW TO STUDY & COLLECT SHELLS	562.32		
RARE & ENDANGERED SPECIES	11.50		
BULLETIN, Back Issues	218.27		
TESKEY INDEX	240.50		
Reprints To Authors	270.04	1302.63	
Page Charges To Authors	645.50		
Contributions To Legal Defense Fund	54.53		
Donations—Returns on Dues Notice Forms	147.00		
Miscellaneous Receipts	33.38	880.41	
Total Receipts From Activities:		8107.46	8107.46
TOTAL CASH ACCOUNTED FOR:			11238.17

DISBURSEMENTS:

BULLETIN, Printing, Postage, Etc.	3433.40		
NEWSLETTERS, Printing, Postage, Etc.	1127.89		
TESKEY INDEX, Type Setting	900.00		
NAUTILUS, Advertising	19.69		
Reprints For Authors	583.26		
Conservation Committee	80.07		
Legal Fee	50.00		
President's Expenses	21.20		
Adding Machine (Used) For Treasurer	50.00		
Editor's Expenses	200.00		
California Filing Fee	5.00		
Officers' Expenses To Meeting (2)	534.97		
Other Postage	301.13		
Other Printing	162.54		
Office Supplies	26.78		
Miscellaneous	76.32	7572.25	
Repayment of Loan On Certificate of Deposit	1703.66		
Interest Paid On Above Loan	137.06	1840.72	
Total Disbursements:		9412.97	

CHECK BOOK BALANCE, DECEMBER 31, 1976

TOTAL CASH ACCOUNTED FOR:

1825.20
11238.17

Savings Acct. #2-6621, 1st. Federal Savings	10.00	
Interest added	.54	
Balance on hand 12/31/76		10.54
Cert. of Deposit #6003332 02, 1st Federal Savings	3619.99	

Int. added	124.26	
Bal. on hand when acct. closed. New acct opened, at maturity of CD, 7/10/76	3744.25	
Savings Acct. \$1121-06 opened, 7/10/76	3744.25	
Interest added	101.05	
Balance on hand 12/31/76		<u>3845.30</u>
Total savings:		3855.84

RECAPITULATION OF ASSETS, DECEMBER 31, 1976:

Cash in checking account, Broadway Nat'l Bank	1825.20
Treasurer's Petty Cash, Myra L. Taylor	25.00
Secretary's Petty Cash, Constance Boone	75.00
Savings Acct. #2-6621, 1st. Federal Savings	10.54
Savings Acct. #1121-06, 1st Federal Savings	3845.30
TOTAL ASSETS:	<u>5781.04</u>
ALLOCATED TO LIFE MEMBERSHIP FUND:	<u>2083.21</u>
A.M.U. NET WORTH, DECEMBER 31, 1976	<u>3697.83</u>
CHANGES IN CAPITAL ACCOUNT:	
A.M.U. CAPITAL ACCOUNT, JANUARY 31, 1976	3027.61
A.M.U. CAPITAL ACCOUNT, DECEMBER 31, 1976	3697.83
NET INCREASE IN ASSETS IN 1976	<u>670.22</u>

Respectfully submitted,
Myra L. Taylor
Treasurer

REPORT FROM THE RECORDING SECRETARY

A report on the state of membership for the fiscal year of 1976 is charted below. It is important because it reflects the effect of the increased dues rates which began Jan. 1, 1976.

Honorary Life President	1
Honorary Life Members	6
Regular Members	
(All Western Hemisphere)	544
Additional Family Members	96
Foreign Corresponding Members	18
Affiliated Members: (Institutions)	
Domestic	34
Foreign	13

Clubs, regional organizations	45
Life Members	<u>27</u>
Total	784
Subscriptions to Bulletin Only	5

The total figure for 1975 was 812 with 4 subscriptions. Therefore, we show a decrease in memberships from all categories of 28. We show one new subscription.

My records indicate the completion of one new life member in 1976, five deaths have been reported, and there were three resignations. Unpaid memberships were 97 from all categories.

Therefore, we show an enrollment of 77 new

and reinstated members in 1976. This is less than the 109 new and reinstated members in 1975. A special effort to solicit new members was made through letters and ads in the latter part of 1975 and the first half of 1976.

Of the 1975 new members we enrolled, 20 did not join again in 1976.

As of June 30, 1977, we have enrolled 34 new members and affiliates, completed one more life member, have been notified of three deaths, and have received three resignations.

Dr. R. Tucker Abbott has continued his bonus gift of copies of *American Malacologists* and the 1975 *Supplement* to new members. A letter has been sent him acknowledging his gift packets to 75 new members, institutions and clubs in 1976.

As hopefully promised in the report last year, expenditures of this office were pared to \$162.47 for the fiscal year 1976. This is \$103.43 less than fiscal year 1975. However, no supplies were purchased in 1976. Some supplies will be needed in 1977. Most of the cost is postage to answer mail, to write new members and send them Newsletters, to mail

Bulletins, copies of the *Index* and the *Symposium of Rare and Endangered Species* purchased during the year. We have had a number of large orders in 1976 and continue to have some in 1977.

With postage rates continuing to rise, we continue to remind all members to update addresses. Repeated announcements in the Newsletters have helped. The situation seems to be satisfactory at present. Approximately ten returns from each mailing this year is noted.

Mailing tabs are being handled by the Publications Editor, with names and addresses being supplied by the Recording Secretary.

The meeting transportation charge to AMU by the Recording Secretary for 1976 was \$150.00. No charges are made for telephone calls to other officers and for incidental expenses for packing materials for orders or for minor office supplies taken from home stock of materials.

Respectfully submitted,

Constance E. Boone

REPORT FROM THE CORRESPONDING SECRETARY

About \$300 worth of books — 174 copies of *How to Study and Collect Shells* — were sent off via mail order, with large multiples going to steady customers like the American Museum of Natural History, Of Sea and Shore and the Smithsonian Institution.

Some of these were sold under the reduced rates suggested by Dr. R. Tucker Abbott who obtained storage for the extra copies, sending boxes to us on request.

The number of letters seeking information has dropped considerably. Much of the mail comes at the start of the school year, apparently reflecting the

desire of students to study this field. Another group of letters came at the beginning of cold weather, indicating possibly trips being contemplated to Florida and pleasures of shelling along those shores.

A release on the Naples meeting of the AMU was prepared and sent to at least five publications. To our knowledge, at least two used the article.

Because of reduced activities, costs were low and expenses under \$25.

Respectfully submitted,

Paul R. Jennewein

CONSERVATION REPORT, 1976-1977

A letter opposing further construction on the Cross Florida Barge Canal and urging its restoration to natural conditions was sent to Florida Governor Askew and members of his Cabinet. This letter included malacological data from a study conducted by Dr. Fred G. Thompson. It was read into the record at the Corps of Engineers' public hearing on the canal at Orlando on 28 September 1976 by Mrs.

Jeanne Whiteside. Governor Askew and his Cabinet have since withdrawn their state's support of the canal, but the project has not been deauthorized by Congress.

In response to a request from Richard M. Parsons, Chief, Federal Wildlife Permit Office, United States Department of Interior, a letter was sent regarding the proposed addition of five taxa of mollusks to

Appendix II of the Convention on International Trade in Endangered Species of Wild Flora and Fauna. The letter requested copies of supportive documentation or scientific studies for evaluation of the proposed taxa, especially *Harpa costata*, *Cypraea cribellum*, and *Cypraea esontropia*. It noted that the AMU Executive Committee on Conservation opposed the listing of "*Helix* spp. (except *H. aspersa*)" and "*Partulidae* spp.," noting that genera and families are subject to varying interpretation by taxonomists through time, and that introduced populations of some species within such taxa, especially *Helix*, have become serious garden pests in some areas.

The possibility of AMU input to the proposed rulemaking (Federal Register, 28 April 1976, vol. 40, no. 83, pp. 17742-47) which would determine 15 U.S. snails to be Endangered Species and 17 such snails to be Threatened Species was explored in a letter to Keith M. Schreiner, Endangered Species Program Manager, U.S. Fish and Wildlife Service. As of the date of this meeting (July, 1977), none of these species or the mollusks proposed in a later issue of the Federal Register (12 January 1977, vol. 42, no. 8, pp. 2507-2515) have been officially listed. There are no American gastropods

now listed as either endangered or threatened by the Department of Interior. One foreign land snail species, 22 species of U.S. bivalves, and 2 foreign bivalve species are listed as endangered species at present.

A questionnaire concerning AMU's role in natural area protection, sent out by The Nature Conservancy as part of a study they are conducting under contract with the National Park Service, was filled out and returned.

In the case of Big Darby Creek, the City of Columbus won a lower court decision declaring the State of Ohio's Scenic Rivers Act unconstitutional. This decision is being appealed by the Ohio Department of Natural Resources, and is expected to be heard by the Ohio Supreme Court. On behalf of the AMU, Rivers Unlimited, The Darby Creek Association, Inc., and The Ohio Environmental Council, the law firm of Segreti and Tousey has filed a Motion for Leave to File Brief of Amici Curiae in this case.

Respectfully submitted,
Carol B. Stein, Chairman
Executive Committee on Conservation
Jeanne Smith Whiteside, Chairman
Conservation Committee

THE AMERICAN MALACOLOGICAL UNION, INC. ACTIVE MEMBERS 1977

Membership List Revised October 15, 1977

- Abbott, Dr. R. Tucker, P.O. Box 4208, Greenville, DE. 19807.
Aguayo, Dr. Carlos G., Dept. of Biology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708.
Ahlstedt, Steven, 34 East Norris Rd., Norris, TN. 37828. (Biological Aide in Fisheries, TVA).
Albert, Mr. and Mrs. Ernest, 905 S. Bayshore, Safety Harbor, FL. 33572.
Alexander, Robert C., 423 Warwick Rd., Wynnewood, PA. 19096.
Allen, James E., 1108 Southampton Dr., Alexandria, LA. 71301 (Tertiary miro-mollusca.)
Allen, Dr. J. Frances, 7507 23rd Ave., Hyattsville, MD. 20783.
Allen, Mrs. Lawrence K., Box 822, Port Isabel, TX. 78578 (*Murex*, *Pecten*, world marines; dealer).
Allen, Miss Letha S., 187 Argyle St., Yarmouth, Nova Scotia, Canada B5A 3X2 (General).
Anders, Kirk W., Shells of the Sea, Inc., P.O. Box 1418, Ft. Lauderdale, FL. 33302 (Volutidae, all rare shells.)
Anderson, Carleton Jay Jr., 56 Kettle Creek Rd., Weston, CT. 06883.
Anderson, Richard V., Dept. of Biological Scs., Northern Ill. Univ., DeKalb, IL. 60115 (Freshwater Pelecypods).
Andrews, Dr. Jean, 241 Melrose, Corpus Christi, TX. 78404.
Armington, Mr. and Mrs. Stewart F. Jr., 15932 Brewster Rd., Cleveland, OH. 44112 (*Cypraea* of Australia).
Arnold, Charles E., 3206 Floyd Ave., Richmond, VA. 23221 (Collecting, photographing).
Ashwell, James R., 2125 Mohawk Trail, Maitland, FL. 32751 (General).
Atheam, Mr. and Mrs. Herbert D. Museum of Fluvial Mollusks, Rt. 5, Box 499, Cleveland, TN. 37311 (Freshwater mollusks.)
Atheam, Mrs. Roy C., 5105 N. Main St., Fall River, MA. 02720 (Land shells).
Avellanet, Mrs. Helene, 105 Clipper Way, Fair Winds Villas, Nokomis, FL. 33555.
Avery, Mrs. Rada G., Box 2557, Harbor, OR. 97415 (West American mollusks; exchange).
Babrazkai, Mr. Noorullah and Dr. Sianoosh Sam Sam, Dept. General Biology, Univ. of Arizona, Tucson, AZ. 85721.
Baerreis, David A., Dept. of Anthropology, 5240 Social Science Bldg., Madison, WI. 53706 (Paleoecological interpretation through mollusks).
Baily, Dr. Joshua L. Jr., 4435 Ampudia St., San Diego, CA. 92103.
Baker, Mrs. Horace B., 11 Chelton Rd., Havertown, PA. 19083.
Baker, John A., 147 Hedgegrove Ave. Satellite Beach, FLA. 32937 (General).
Baker, Sam and Candi, son Jeffrey, 1530 Astec Circle, Naperville, IL. 60540 (Collecting cones and cowries).
Barker, C. Austin, 2 Hickory Dr., Rye, NY. 10580.
Barlow, Mrs. G. Barton, 5 Downey Dr., Tenafly, NJ. 07670.
Barnett, Mr. and Mrs. George H., Koran Ave., MD. #23, Newburgh, NY. 12550.
Barr, John W. Jr., 380 Westwood Place, Apt. 5, Austell, GA. 30001 (Cypraeidae).
Bates, Dr. John M., 1900 Dexter Ave., Ann Arbor, MI. 48103.
Bauer, Mr. and Mrs. Hugo C., 2126 45th St., Galveston, TX. 77550 (all Mollusca).
Baum, Newman N., 83 Weaving Lane, Wantagh L.I., NY. 11793.
Bazata, Kenneth R., Nalco Environmental Sciences, 4010 Northwest 39th St., Lincoln, NB. 68524.
Bears, David T., Grad. School of Oceanography, Univ. of R.I., Kingston, RI 02881 (Shellfisheries).
Beasley, Clark W., Dept. of Biology, McMurry College, Abilene, TX. 79605 (Terrestrial and freshwater mollusks).
Beetle, Ms. Dorothy E., 375 W. Galbraith Rd. #42, Cincinnati, OH. 45215. (U.S. Land & F.W. Moll.).
Bennett, Sally, 514 W. Rose Lane, Phoenix, AZ. 85013. (Panamic Province shells).
Bequaert, Dr. Joseph C., 3033 E. 6th St., Tucson, AZ. 85716.
Bereza, Daniel J., 825 N. 24th St., Philadelphia, PA. 19130 (Unionidae; Pleuroceridae).
Berke, Ian, 4032 23rd St., San Francisco, CA. 94114.
Berry, Dr. and Mrs. Elmer G., 8506 Beech Tree Court, Bethesda, MD. 20034.
Berry, Dr. S. Stillman, 1145 W. Highland Ave., Redlands, CA. 92373.
Bianchi, Mrs. Ann, Box 235, Goodland, FL. 33933.
Bickel, David, 1729 N. 5th St., Bismarck, N.D. 58501. (Systematics and ecology of freshwater mollusks, esp. Pleurocerids).
Bijur, Jerome M., 135 Seventh Ave. N., Naples, FL. 33940 (Buy, exchange Florida, Caribbean and Gulf of Mexico marine).
Bing, Ruth Rosser, P.O. Box 2612, Muhlenburg Station, Plainfield, NJ. 07060 (Art-Photography, oil painting).
Bippus, Mr. and Mrs. Alvin C., 2743 Sagamore Rd., Toledo, OH. 43606 (Marine gastropods).
Blaser, James, 1846 Laurel Lane, Amherst, OH. 44001 (Florida mollusks; Ohio freshwater mollusks).
Bleakney, Dr. J. Sherman, Dept. of Biology, Acadia Univ., Wolfville, Nova Scotia, Canada BOP 1X0 Nudibranchs and sacoglossans; ecology, zoogeography, systematics).
Bledsoe, William D., 352 Bon Hill Rd., Los Angeles, CA. 90049.
Body, Ralph L., 2538 10th Ave. W., Seattle, WA. 98119.
Bogan, Arthur E., Research Ass't., Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916.
Boone, Mr. and Mrs. Hollis Q., 3706 Rice Blvd., Houston, TX. 77005.
Borror, Kathy Gail, OSU, Museum of Zoology, 1813 N. High St., Columbus OH. 43210.
Boss, Dr. Kenneth J., Museum of Comparative Zoology, Harvard Univ., Cambridge, MA. 02138.

- Bottimer, L.J., Rt. 1, Box 205, Tow, TX. 78672 (recent and fossil mollusks).
 Boy, Duane M/S 0949, Ecological Services Group, Texas Instruments Inc., Box 5621, Dallas, TX. 75222.
 Boyd, Dr. and Mrs. Eugene S., 6806 Gillis Rd., Victor, NY. 14564 (Phylum Mollusca—all aspects).
 Branson, Dr. Branley A., P.O. Box 50, Eastern Kentucky Univ., Richmond, KY. 40475.
 Bratcher, Mrs. Twila, 8121 Mulholland Terrace, Hollywood, CA. 90046.
 Brean, Clark, 705 E. Sherman, Lebanon, OR. 97355 (Student, Cypraea).
 Bretsky, Sara S., 91 Upper Sheep Pasture Rd., East Setauket, NY. 11733 (Ecology and evolution of Bivalvia, Tertiary and Recent).
 Bricker, Mrs. Minnie, Miss Donna Bricker, R.D. 6, Box 476, Hanover, PA. 17331 (Conchs and Whelks).
 Britton, Dr. Joseph C., Dept. of Biology, Texas Christian Univ., Ft. Worth, TX. 76129.
 Brooks, Mr. and Mrs. John C., 3050 Sunrise Blvd., Ft. Pierce, FL. 33450.
 Brown, Drs. Harvey and Marjorie, 9455 S.W. 81st Ave., Miami, FL. 33156.
 Broyles, Mrs. Ralph E., 5701 Fairfield Ave., Ft. Wayne, IN. 46807.
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 Bryant, John C., 200 Bryant Rd., Hillsboro, OH. 45133.
 Buchanan, Alan, Missouri Dept. of Conservation, Fish & Wildlife Research Ctr., 1110 College Ave., Columbia, MO. 65201 (Fisheries biologist).
 Buckley, George D., 164 Renfrew St., Arlington, MA. 02174.
 Buerk, Dr. Minerva S., Maybrook Chalet, 331 Penn Rd., Wynnewood, PA. 19096 (Anatomy, histology).
 Bullis, Harvey R. Jr., 121 Island Dr., Key Biscayne FL. 33149.
 Burch, Dr. John B., Museum of Zoology, University of Michigan, Ann Arbor, MI. 48104 (Land and fresh water mollusks).
 Burch, Mrs. John Q., 1300 Mayfield Rd., Apt. 61-L, Seal Beach, CA. 90740.
 Burch, Beatrice L., P.O. Box 309, Kailua, HI. 96734 (Dredging).
 Burger, Sybil B., 3700 Gen. Patch N.E., Albuquerque, NM. 87111 (Gulf of Mexico; land snails).
 Burghardt, Mr. and Mrs. Glenn, 11424 Pioneer Ave., Oakdale, CA. 95361.
 Burky, Dr. Albert J., Dept. of Biology, Univ. of Dayton, Dayton, OH. 45469.
 Burr, Raymond, 7476 Hillside Ave., Los Angeles, CA. 90046.
 Campbell, Mrs. Minnie Lee and Donald C., 3895 DuPont Circle, Jacksonville, FL. 32205 (General).
 Capo, Thomas R., 3875 Waldo Ave., Apt. 2 D, Bronx, NY. 10463 (Benthic ecology).
 Cardeza, R. Adm. and Mrs. Carlos M., P.O. Box 6746, Houston, TX. 77005; summer add.—1718 Jewel Box Dr., Sanibel, FL. 33957 (Florida and Texas shells).
 Cardin, MSGT. Charles, 4284 E. Viking Rd., Las Vegas, NV. 89121.
 Carlton, James T., Dept. of Geology, Univ. of California, Davis, CA. 95616 (Estuarine and brackish water mollusks).
 Carney, Dr. W. Patrick, Box 14, NAMRU-2 Taipei, APO San Francisco, CA. 96263.
 Carr, Mrs. Jack C., 912 Broadway, Normal, IL. 61761 (Exchange worldwide marine).
 Carson, John, 221 Elm Ave., Morrisville, PA. 19067.
 Castagna, Michael, Va. Institute of Marine Science, Wachapreague, VA. 23480 (Pelecypod larval behavior).
 Cate, Mr. and Mrs. Crawford N., P.O. Drawer 710, Rancho Santa Fe, CA. 92067. (*Mitra*, *Cypraea*; no exchanges).
 Cetnar, Dr. and Mrs. Eugene J., 4379 Ramsgate Lane, W. Bloomfield, MI. 48013.
 Chace, Emery P., 24205 Eshelman Ave., Lomita, CA. 90717.
 Chadwick, Albert F., 2607 Turner Rd., Wilmington, DE. 19803 (Marine mollusks).
 Chamberlin, Ursula (Mrs. John), Mountain View Rd., Fishkill, NY. 12524 (Compiling collection N. Atl. marines).
 Chandler, Carl B. and Doris M., P.O. Box 621, Chatham, MA. 02633 (Cones, *Cypraea*).
 Chanley, Mr. and Mrs. Paul E., Fisheries Research Div., Ministry of Agriculture & Fisheries, P.O. Box 19062, Wellington, N.Z.
 Chichester, Lyle F., 31 Chamberlain St., New Britain, CT. 06052 (Ecology of terrestrial gastropods, biology of land slugs).
 Christensen, Carl C., Dept. of General Biology, Univ. of Arizona, Tucson, AZ. 85721.
 Christie, John D., Ph.D., The Rockefeller Foundation, 1133 Ave. of the Americas, N.Y., NY. 10036.
 Chorsciechowski, Przemyslaw K., Aptdo. 125, Maracay 3K0, Venezuela (Planorbidae).
 Clarke, Dr. Arthur H., Dept. of Mollusks, USNM, Smithsonian, NHB-E 514, Washington, D.C. 20560.
 Clench, Dr. William J., 26 Rowena St., Dorchester, MA. 02124.
 Clover, Phillip W., P.O. Box 83, Glen Ellen, CA. 95442 (Rare *Cypraea*, *Conus*, *Voluta*, *Murex*, *Marginella*—Buy and exchange).
 Clymer, George M., 378 Quinell Ave., Lakeland, MN. 55043 (Unionidae).
 Coan, Dr. Eugene V., 891 San Jude Ave., Palo Alto, CA. 94306.
 Cohen, Anne C. (Mrs. Daniel M.), Division of Crustacea, NMNH, Smithsonian Institution, Washington, DC. 20560 (*Loliginidae*; *Litiopa melanostoma*).
 Coleman, Dr. Richard W., Dept. of Biology, Upper Iowa College, Fayette, IA. 52142 (Environmental interrelationships, plants-invertebrates).
 Compitello, Mrs. Juliette, 5630 Alta Vista Rd., Bethesda, MD. 20034.
 Conde, Vincent, McGill University (Redpath Museum), Montreal, Canada.
 Cooper, Robert W., 5012 Pfeiffer Rd., Peoria, IL. 61607 (Florida marine; *Murex*, *Pecten*, *Spondylus*, SCUBA).
 Corgan, Dr. James X., Dept. of Geography and Geology, Austin Peary State Univ., Clarksville, TN. 37040 (Microscopic gastropods).
 Cosman, Dieter, 7 Oak Hill Rd., Huntington, N.Y. 11743 (Marine tropical and subtropical Gastropoda and Bivalvia world-wide).
 Countryman, William D., R.D. 1 Northfield, VT. 05663 (Mollusca of Vermont).
 Courtney, Charles M., 990 N. Barfield Dr. Marco Island, FL. 33937 (Aquatic ecologist/malacologist).
 Craig, Katherine B., 24 Savoy St., Colonia, NJ. 07067 (Mollusks of N.E. Coast of U.S.).

- Craine, Mrs. Ruth A., P.O. Box 2001, Southern Pines, NC. 28387.
- Cramer, Frances L., 766 Obispo Ave., Long Beach, CA. 90804 (Ecology; conservation).
- Crissinger, William and Myrna May, 820 N. Court St., Crown Point, IN. 46307.
- Croft, Mrs. Thomas L., 9393 Ladue Rd., St. Louis, MO. 63124 (Marine; fossils).
- Cull, Mrs. Robert R., 7927 Chippewa Rd., Brecksville, OH. 44141.
- Cummings, Raymond, W., 37 Lynacres Blvd., Fayetteville, NY. 13066 (West Indies shells, esp. Windward and Grenadine Is.).
- Cutler, Mr. and Mrs. Henry H., 105 Abbott Rd., Wellesley Hills, MA. 02181.
- Cvancara, Dr. Alan Milton, Dept. Geology, Univ. of N. Dakota, Grand Forks, ND. 58201 (Pleistocene and Holocene continental mollusks, early Tertiary continental and marine).
- Danforth, Louise L., 2529 Terry Lane, Sarasota, FL. 33581.
- Daniels, Mrs. Kathleen K., Box 265 A, Rt. 1, Apollo, PA. 15613 (*Haliotis*, *Murex*, *Spondylus*, *Pectinidae*, *Conus*, *Cypraea*, in order listed).
- Daniels, Ronnie H., 5330 Patrick Henry Dr., Memphis, TN. 38134 (Marine: *Volutes*, *Murex*, *Cowries*).
- Darcy, George H., Univ. of Miami Sch. of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Davenport, Mrs. Lillian B., 802 Cape Ave., Cape May Point, NJ. 08212 (Anything pertaining to the sea).
- Davis, Dr. Derek S., Nova Scotia Museum, 1747 Summer St., Halifax, Nova Scotia, Canada B3H 3A6 (Gastropod biology and taxonomy).
- Davis, Dr. George M., Dept. of Malacology, ANSP, 19th and the Parkway, Philadelphia, PA. 19103, and Davis, Dr. Elaine Hoagland, Assistant Professor of Biology, Lehigh Univ., Bethlehem, PA. 18015.
- Davis, Dr. John D., 26 Norfolk Ave., Northampton, MA. 01060 (Ecology of marine bivalves).
- Deatrick, Paul A., 218 S.W. 32 Ave., Miami, FL. 33135 (*Strombus*, *Busycon*).
- de Graaff, Gerrit, 10915 S.W. 55 St., Miami, FL. 33165.
- DeLuca, Mrs. John A. and Mrs. Gladys DeLuca, 61 Deborah Rd., Hanover, MA. 02339.
- Demond, Miss Joan, 4140 Grandview Blvd. #1, Los Angeles, CA. 90066.
- Dennis, Ms. Sally, TVA, Forestry, Fisheries, and Wildlife Develop., Norris, TN. 37828 (Freshwater mussels).
- DeOliveira, Dr. Maury Pinto, Dept. Biologia-Malacologia, Universidade Federal De Juiz De Fora, Cidade Universitaria, 36100 Juiz de Fora, Minas Gerais, Brazil.
- Dexter, Miss Norma, 135 E. Main St. #3, Clinton, CT. 06413 (*Cypraea*).
- Dexter, Dr. and Mrs. Ralph W., Dept. Biological Science, Kent State Univ., Kent, OH. 44242.
- Dietrich, Mr. and Mrs. Louis E., 308 Veri Dr., Pittsburgh, PA. 15220.
- Dillon, Robert T., Jr., 1140 Club Rd., Waynesboro, VA. 22980.
- Dixon, Mrs. Ruth S., 711 Parker St., Durham, NC. 27701 (Marine).
- Dolin, Eric, 107 Briar Brae Rd., Stamford, CN. 06903 (*Conus* *Cypraeidae*, *Strombus*, *Voluta*).
- Draper, Bertram C., 8511 Bleriot, Los Angeles, CA. 90045 (Eastern Pacific minute mollusks and all Western U.S. marine).
- Druger, Dr. George, Memorial Hospital Medical Bldg., 500 Memorial Ave., Cumberland, MD. 21502 (SCUBA).
- DuBar, Dr. and Mrs. Jules R., Lakeview Hgts., Morehead, KY. 40351 (Cenozoic and recent mollusks—ecology and palaeoecology).
- Dugdale, H.K., P.O. Box 1392, Wilmington, DE. 19899 (Editor, Chambered Nautilus Newsletter).
- Dundee, Dr. Dolores S., Dept. of Biology, Univ. of New Orleans-Lakefront, New Orleans, La. 70122 (Land mollusks, freshwater mussels).
- Dvorak, Stanley J., 3856 W. 26th St., Chicago, IL. 60623 (Muricidae).
- Dyer, Mr. and Mrs. John S. Jr., Box 238, Brookside, NJ. 07926 (Gastropods).
- Eakle, Christine E., Rackey, William A., 2308 Breton Dr., District Heights, MD. 20028 (Worldwide collecting).
- Eddison, Grace G., M.D., "Wildwood," Rt. 4, Carlisle, KY. 40311.
- Edwards, Lt. Col. Corinne E., USAF (Ret.), P.O. Box 691, Coconut Grove, FL. 33133 (Chitons; self-collected).
- Edwards, D. Craig, Dept. of Zoology, Morrill Science Center, Univ. of Massachusetts, Amherst, MA. 01022 (Population ecology and behavior of marine benthic molluscs).
- Emerson, Dr. William K., American Museum of Natural History, Central Park West at 79th St., New York, NY. 10024.
- English, Rita C. and English, James F., 10300 Terrace Court, Parma, OH. 44130 (Fossils; Florida and Caribbean; ecology of mangrove areas).
- Erickson, Carl W., 4 Windsor Ave., Auburn, MA. 01501.
- Eubanks, Dr. Elizabeth R., 2162 E. Minton Dr., Tempe, AZ. 85282 (Florida marine).
- Evans, Miss Susan E., 244 Congress Ave., Lansdowne, PA. 19050 (*Conus*, *Cypraea*, *Murex*).
- Evans, Roger, 1900 Camino de la Costa, Apt. 1, Redondo Beach, CA. 90277 (Diver; marine mollusks of Southern California).
- Eversole, Dr. Arnold G., Dept. of Entomology and Economic Zoology, Clemson Univ., Clemson, SC. 29631 (Interpopulation variation and bioenergetics of molluscan populations).
- Everson, Gene D., 1660 SW 27th Ave., Ft. Lauderdale, FL. 33312 (World-wide collection with emphasis on Florida, Caribbean and miniatures).
- Fackert, Miss Dorothy M., 2 Wilson Rd., Apt. 16B, Sussex, NJ. 07461.
- Fair, Ruth H., 15135 Memorial Dr. #49, Houston, TX. 77079.
- Feichtner, Frederick R., 2611 W. Fitch Ave., Chicago, IL. 60645.
- Feinberg, Harold S., Dept. of Fossil and Living Invertebrates, American Museum of Nat. Hist., Central Park West at 79th St., N.Y., NY. 10024 (Land and freshwater mollusks).
- Ferguson, Dr. and Mrs. John H., 226 Glandon Dr., Chapel Hill, NC. 27514.
- Ferreira, Dr. Antonio J., 2060 Clamar Way, San Jose, CA. 95128 (Ecology, behavior, physiology, systematics of American Mollusca).
- Fieberg, Mrs. Kleinie, 1430 Lake Ave., Wilmette, IL. 60091.
- Finlay, C. John, 116 Tanglewood Lane, Newark, DE. 19711 (Marine mollusks Western Atlantic and Caribbean).
- Foehrenbach, Jack, 91 Elm St., Islip Manor, NY. 11751 (Marine ecology).

- Fontanier, Charles E., P.O. Box 9325, Fort Worth, TX. 76107 (Cypraeidae, Unionidae; Scuba).
- Footo, Miss Mary K., Apt. 418, 7201 Spencer Hwy., Pasadena, TX. 77505.
- Forrest, Frank, 2717 Vinewood Dr., Speedway, IN. 46224.
- Foster, Mr. and Mrs. Edward W., 30 Bamboo Dr., Naples, FL. 33940.
- Foster, Mrs. Fred H., 401 N. Justus St., Oxford, IN. 47971.
- Fowler, Dr. and Mrs. Lake, 4508 Woodrow, Galveston, TX. 77550.
- Franz, Dr. David R., Biology Dept., Brooklyn College, Brooklyn, NY. 11210 (Ecology and physiology, marine mollusks, esp. Nudibranchs).
- Franzen, Dr. Dorothea, Illinois Wesleyan Univ., Bloomington, IL. 61701.
- Fraser, Stanley, Box 966, Smiths Falls, Ont., Canada K7A 5A5.
- Frye, Mark W., Dept. of Geology and Mineralogy, OSU, 125 S. Oval Mall, Columbus, OH. 43210 (Naiads, Micropaleontology with specialty in Ordovician micro-mollusks).
- Fuller, Samuel L.H. and Mrs. Mary L.B. Fuller, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (World Naiads, Unionacea and Mutelacea).
- Fullington, Richard W. and Kate E., 215 Bonnie Brae, Denton, TX. 76201.
- Gallindo, Lic. Ernesto Santos, Jorge Elliot #12, Colonia Polanco, Mexico, D.F. 5.
- Gardner, Mrs. Sandra M., 1755 Univ. Ave., Palo Alto, CA. 94301.
- Galler, Mr. and Mrs. Leonard, 336 DeMott Ave., Rockville Centre, NY. 11570.
- Germer, Mr. and Mrs. John R., 653 Braircliff Ave., Maywood, NJ. 07607 (Mr., Photography of shells; Mrs., *Pectens* and *Murex*, shells of E. and W. Atl.).
- Germon, Mrs. Raye N., 27 Rosemont Dr., Gaithersburg, MD. 20760 (*Murex*, *Volute*, *Cypraea*, *Latiaxis*, marine fossils).
- Gibbons, Ms. Mary C., RD 2, Box 28, Clay Rd., Lewes, DE. 19958 (Grad student at College of Marine Studies, U. of Delaware).
- Gilbert, Mrs. Laura, 808 Westwood Dr., Abilene, TX. 79603.
- Gilbert, Dr. William H. and Dr. Mary Ann Gilbert, Environmental Studies, Ottawa Univ., Ottawa, KS. 66067.
- Gilmour, Dr. Thomas H.J., Dept. Biology, Univ. of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0 (Anisomyarian bivalves).
- Girardi, Dr. Elizabeth-Louise, 707 Kent Rd., Kenilworth, IL. 60043.
- Glazebrook, Sandra R., 7760 Margerum Ave. #228, San Diego, CA. 92120.
- Glick, Dr. Robert N. 13500 E. 12 Mile Rd., Warren, MI. 48093 (Cowries, cones, olives).
- Goethel, Lt. Col. (Ret.) and Mrs. Louis N., 9402 Nona Kay Dr., San Antonio, TX. 78217 (*Cypraea*—buy and trade).
- Gold, Albert, 118 W. 227 St., Bronx, N.Y. 10463.
- Goldberg, Michael, 6927 Williams Dr., Tampa, FL. 33614.
- Goodfriend, Glenn A., Comm. on Evol. Biology, U. of Chicago, IL. 60637 (Molluscan ecology).
- Gordon, Mackenzie Jr., Paleontology and Stratigraphy Branch, U.S. Geological Survey, Smithsonian, Washington, D.C. 20560.
- Greenberg, Bayle, c/o Tidepool Gallery, 3907 W. 50th St., Edina, MN. 55424.
- Greenberg, Mrs. Janis, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greenberg, Mrs. Ruth, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Guckert, Richard H., 1757 Kimberly Dr., Marietta, GA. 30060 (Systematics of freshwater mussels; ecology; physiology of Nassariidae).
- Gudnason, Mrs. Harold, 105 Danefield Place, Moraga, CA. 94556.
- Gugler, Dr. Carl W., School of Life Sciences, U. of Neb., Lincoln, NB. 68588.
- Gunter, Dr. Gordon, Gulf Coast Research Lab., Ocean Springs, MS. 39564 (Ostreidae).
- Gussman, David S., 1141 Laguna Ave., Apt. #3, Burlingame, CA 94010. (Aquatic ecology, feeding dynamics of aquatic organisms).
- Haas, Dr. John W., 1653 Medical Arts Bldg., Minneapolis, MN. 55402 (*Volutes*, *Pectens*, *Spondylus*).
- Hagge, Mrs. Daniel, 20 North Hill Rd., Wausaw, WI. 54401.
- Haigh, Ernest S., 6533 Orangewood Ave., Cypress, CA. 90630.
- Hall, Eleanor R., 1230 N.E. 88th St., Seattle, WA. 98115 (Marine gastropods, esp. worldwide *Cypraea*).
- Hall, Mrs. Warner L., 727 Queen's Rd., Charlotte, NC. 28207.
- Hamilton, Dr. Paul V., Assistant Professor, Biology, Univ. of W. Florida, Pensacola, FL. 32504 (Behavior and ecology of gastropods).
- Hamilton, Mrs. William J. Jr., 615 Highland Rd., Ithaca, NY. 14850.
- Hammer, Richard M., 2226-D Voorhees, Ave., Redondo Beach, CA. 90278 (Marine mollusks—worldwide).
- Hand, Dr. Cadet H., Bodega Marine Lab, P.O. Box 247 Bodega Bay, CA. 94923.
- Harasewych, Jerry, Delaware Museum of Natural History, Box 3937, Greenville, DE. 19807.
- Hargreave, Dr. David, Ass't. Prof. Nat. Scs., College of Gen. Studies, Western Mich. Univ., 1104 Berkshire Dr., Kalamazoo, MI. 49007 (Collecting and photography).
- Harman, Dr. Willard N., Box 63, Otego, N.Y. 13825 (Freshwater mollusca).
- Harris, Don V. Jr., 4525 Glebe Rd. N., Arlington, VA. 22207.
- Harris, Mr. & Mrs. E. Milton, 3237 Carlisle Rd., Birmingham, AL. 35213.
- Harris, Major Marion J. and Mrs. Bessie B. Harris, 28 Sylvan Ave., Wallingford, CT. 06492.
- Harry, Dr. Harold W., 4612 Evergreen St., Bellaire, TX. 77401.
- Hartman, Joseph H., Dept. Geology/Geophysics, Univ. of Minn. 108 Pillsbury Hall, Minneapolis, MN. 55455 (Cretaceous-Eocene F.W. moll. of W. US; Viviparidae).
- Haven, Dr. Dexter S., 336 Lafayette Rd., Yorktown, VA. 23690 (*Mercenaria mercenaria*, *Mya arenaria*, *Crassostrea virginica*).
- Havens, Miss Susan E., 21 Varnum Ave., Pawtucket, RI. 02860 (Student).
- Havlik, Mrs. Marian E., 1603 Mississippi St., LaCrosse, WI. 54601 (Naiads of Miss. River).
- Hedges, Arlene J., 404 North East St., Crown Point, IN. 46307.
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- Hickey, Ms. Mary T., 4415 Independence St., Rockville, MD. 20853 (Scallops).

- Hickman, Carole S., Dept. of Paleontology, Univ. of Calif., Berkeley, CA. 94720 (tertiary molluscan paleontology).
- Hickman, Mrs. Harriette L., 20 Wilkie Blvd., Mamora, NJ. 08223 (Worldwide *Epitonium*).
- Hicks, Mr. and Mrs. Edwin S., 1522 Palmwood Dr., Eau Gallie, FL. 32935 (Recent and fossil marine shells of Western Atlantic).
- Higbee, Mrs. Florence and Dr. Joan Higbee, 13 North Bedford St., Arlington, VA. 22201.
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- Hillman, Dr. Robert E., Battelle-Clapp Laboratories, Duxbury, MA. 02332 (Molluscan ecology and physiology).
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- Hohman, Betty Jean, 10 Ferris, Apt. 101, Highland Park, MI. 48203 (cones, Volutes, Muricea).
- Holiman, Mr. and Mrs. Wayne, Box 246, Edinburg, TX. 78539.
- Holle, Dr. Paul A., 131 Holman St., Shrewsbury, MA. 01545 (Salt marsh snails).
- Hollister, S.C., 5 Parkway Place, Ithaca, NY. 14850.
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- Houbrick, Dr. Richard S., Div. of Mollusks, Smithsonian, Washington, D.C. 20560 (Zoogeography, systematics, evolution).
- Houtzel, David B., RR2, Pontiac, IL. 61764 (Desires correspondence and exchange).
- Hubbard, Mrs. Marian S., 3957 Marlow Court, Seaford, NY. 11783 (Littorinidae; all juvenile mollusks).
- Hubricht, Leslie, 4026 35th St., Meridian, MS. 39301 (U.S. land and freshwater).
- Hulswit, Mr. & Mrs. Mart, 680 West End Ave., New York, NY. 10025 (SCUBA).
- Hunkins, Mrs. Ruth E., 133 Brook to Bay, Englewood, FL. 33533 (Miniature shells; exchange).
- Hyett, Dr. and Mrs. Marvin R., 403 Silverhill Rd., Cherry Hill, NJ. 08034.
- Imlay, Dr. Marc J. and Alice, Fish Wildlife Service, Dept. of Int., Office of Endangered Species, 1612 K. St. N.W., Washington, DC. 20240.
- Ing, Mrs. Mary C. and Michael B. Ing, Bella Vista Hospital Box 1750, Mayaguez, Puerto Rico 00708 (Small and minute shells of W.I.).
- Ishikawa, Samuel, 551 Fifth Ave., New York, NY. 10017.
- Isom, Billy G., Rt. 2, Box 217, Amy Drive, Killen, AL. 35645.
- Jackson, Ralph W., Rt. #1, Box 229, Cambridge, MD. 21613 (Exchange land shells).
- Jacobson, Morris K., Oct. to April, 865 Capon St. S.E., Palm Bay, FL. 32905; April to Oct., 455 Beach 139 St., Rockaway Beach, NY. 11694.
- Jacobson, Mrs. Ursula, 5618 E. Montecito, Phoenix, AZ. 85018 (Indo-Pacific, esp. cones and cowries; West Coast-Panamic).
- James, Brian, 24 The Links Rd., Apt. 210, Willowdale, Ont., Canada.
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- Janowsky, Robert and Dorothy, 946 Ralph Ave., Brooklyn, NY. 11236 (*Cypraea*, *Murex*, Volutes).
- Jass, Ms. Joan, 1171 N. 44th St., Milwaukee, WI. 53208.
- Jenkinson, John J. and Carolyn, 189 W. Lakeview Ave., Columbus, OH. 43202.
- Jenner, Charles E., Dept. of Zoology, Univ. of N.C., Chapel Hill, N.C. 27514 (Biology of *Ilyanassa*, *Solemya*, and commensal bivalves).
- Jennewein, Paul R. and Virginia N., Box 394, Wrightsville Beach NC. 28480 (Raising mollusks in aquaria; writing and illustrating articles on shell collecting).
- Jensen, Russell H., R.D. #1, Box 55, Chadds Ford, PA. 19317 (Mollusks of Bermuda).
- Johns, Veronica Parker, c/o Seashells Unlimited, Inc., 590 Third Ave., New York, NY. 10016.
- Johnson, Col. Harvey A. (Ret.) 3915 S.W. 109th St., Seattle, WA. 98146.
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- Johnson, Richard I., 124 Chestnut Hill Rd., Chestnut Hill, MA. 02167.
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- Johnstone, Mrs. Kathleen Yerger, 2209 River Forest Rd., Mobile, AL. 36602.
- Jokinen, Eileen (Romach), Biology Dept., Suffolk Univ., Boston, MA. 02114 (Freshwater gastropods).
- Jones, Mr. and Mrs. Archie L., 4370 S.W. 14 St., Miami, FL. 33134 (*Liguus*).
- Jones, Meredith L., Division of Invert. Zoology, USNM, Smithsonian Institution, Washington, DC. 20560.
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- Kay, Dr. E. Alison, Graduate Division, 2540 Maile Way, Univ. of Hawaii, Honolulu, HI. 96822 (Indo-Pacific marine; systematics and ecology).
- Keegan, Mrs. Barbara, 54 Franklin St., Franklin, NH. 03235.
- Keeler, James H., 30 Park Lane, Chagrin Falls, OH. 44022 (Marine, esp. micro Gastropods-Epitonidae and Terebridae).
- Keen, Dr. A. Myra, Dept. of Geology, Stanford Univ., Stanford, CA. 94305.
- Keferl, Dr. Eugene P., Div. of Natural Science, Brunswick Junior College, Altama at Fourth, Brunswick, GA. 31520 (Terrestrial gastropods).
- Kellogg, Michael G., Dept. Invert. Zoology, California Academy of Sciences, San Francisco, CA. 94118.
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- King, Lucia E., Heron Club, 434 Broad Ave. South, Naples FL. 33940.
- Kline, Mrs. George F., 240 Makee Rd., Apt. 10-A, Honolulu, HI. 96815.
- Klinkey, Mrs. Martha, 1336 S. 14th St., St. Charles, IL. 60174. (*Cypraea*, *Murex*, *Strombus*).
- Kohn, Dr. Alan J., Dept. Zoology, Univ. of Washington, Seattle, WA. 98165.
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- Kondo, Dr. Yoshio, 809 A. Isenberg St., Honolulu, HI. 96814.
- Kotrla, M. Bowie, Dept. of Biology, Trinity Univ., 715 Stadium Dr., San Antonio, TX. 78284 (Parasites of snails).

- Kovach, Jack, Dept. of Geology, Muskingum College, New Concord, OH. 43762 (Ecology, shell composition, paleontology of non-marine).
- Kraemer, Dr. Louise Russert, Dept. of Zoology, Univ. of Arkansas, Fayetteville, AR. 72701 (Freshwater lamellibranchs).
- Kraeuter, Dr. John N., Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Ecology, distribution and systematics of Scaphopoda; benthic infaunal of U.S. East Coast).
- Krauss, N.L.H., 2437 Parker Place, Honolulu, HI. 96822 (Carnivorous land snails; biology).
- Kuczynski, Mrs. Florence, 7400 N. 46th Ave., Box 406, St. Petersburg, FL. 33709 (Collect, exchange, photograph shells).
- Kurz, Richard M. 1575 N. 118 St., Wauwatosa, WI. 53226 (Specimen shells).
- Kuzirian, Alan M., 93 Exeter Rd., Hampton, N.H. 03842. (Nudibranch biology).
- Laavy, T.L., Rt. 5, Maruca Dr., Greenville, SC. 29609.
- Lalli, Dr. Carol M., Marine Sciences Centre, Box 6070, Station A, McGill Univ., Montreal, Que., Canada H3C 3G1 (Pteropods).
- Lamberts, Dr. Austin, 1520 Leffingwell, N.E., Grand Rapids, MI. 49505 (Coral reefs and associated mollusks).
- Landye, James Jerry, 3465 N. Jamison, Flagstaff, AZ. 86001.
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- Lane, Dr. Roger L., Ashtabula Campus, Kent State Univ., Ashtabula, OH. 44004 (Morphology, Histology).
- Lange, W. Harry, Dept. of Entomology, Univ. of California Davis, CA. 95616.
- Langworth, Richard M. and Barbara F., 20 Hart Ave., Hopewell, N.J. 08525 (Cowries and volutes).
- LaRocque, Dr. Aurele, 102 W. Beaumont Rd., Columbus, OH. 43214.
- Laursen, Dr. Dan, 4901 East Eastland, Tucson, AZ. 85711 (Arctic, Subarctic mollusks; Free living larvae of Caribbean and Gulf areas).
- Lee, Dr. Harry G., 709 Lomax St., Jacksonville, FL. 32204.
- Lee, Pamela, 2146 Mt. Olympus Dr., Los Angeles, CA. 90046 (Marine).
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- Lencher, Mrs. Jennie R., 144 N. Dithridge St., Apt. 408, Pittsburgh, PA. 15213.
- Lenhard, Louis, Abbey School, Canon City, CO. 81212. (Terrestrial mollusks).
- Leonard, Dr. A. Byron, 562 Snow Hall, Univ. of Kansas, Lawrence, KS. 66045.
- Lerner, Martin, 64 Thompson Ave. Oceanside, NY. 11572 (Worldwide marine).
- Leslie John, B-122 Birge Hall, Univ. of Wisconsin, Madison, WI. 53706 (*Haliotis*).
- Lewis, Harold, 138 S. Twentieth St., Philadelphia, PA. 19103.
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- Lewis, Randall B., 210 Chandler Dr., Munele, IL. 60060.
- Lindberg, David R., Dept. of Invert. Zoology, Calif. Academy of Sciences, Golden Gate Park, San Francisco, CA. 94118.
- Linsley, Robert M. Dr., Dept. of Geology, Colgate Univ., Hamilton, NY. 13346.
- Lipe, Robert and Mrs. Bette Lipe, 8929-91st Terrace, Seminole, FL. 33542 (Florida shells; Marginellidae worldwide; photography).
- Littleton, Thomas G., 511 Colonial Parkway, Devine, TX. 78016.
- Long, Dr. Glenn A., 608 Stevenson Lane, Towson, MD. 21204 (Ethnoconchology).
- Long, Steven J., 3651 Via Lato, Lompoc, CA. 93436 (Opisthobranchs, Nudibranchs, Cephalaspideans, Notaspideans, Lamellarians).
- Lopinot, A.C., 45 Northcrest, Litchfield, IL. 62056 (Aquatic biologist, taxonomy and life history of freshwater mussels).
- Lowry, Walter G. and Nelle H., 552 Old Lundy Rd., Macon, GA. 31204 (Collect N.C. marine, exchange).
- Lubinsky, Dr. Irene, 32 Thatcher Drive, Winnipeg, Man., Canada, R3T 2L2, (Marine bivalves of the Canadian Arctic).
- Lyons, Miss Sarah, 81 Lakeview Ave., N.E., Atlanta, GA. 30305.
- Lyons, William G., Florida Dept. of Natural Resources, Marine Lab, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Florida and West Indian mollusks).
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- Mackie, Dr. Gerry L., Dept. of Zoology, Univ. of Guelph, Guelph, Ont., Canada N1G 2W1 (Sphaeriids).
- MacMillan, Gordon K., 169 Glenfield Dr., Pittsburgh, PA. 15235.
- Macquin, Mrs. Hazelle B., 437 Douglas St., Salt Lake City UT. 84102 (Fossil mollusks of U.S.).
- Madvin, Mrs. Beverly, 24208 Hatteras, Woodland Hills, CA. 91364.
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- Malick, Donald, 5514 Plymouth Rd., Baltimore, MD. 21214 (Buy, sell, exchange fossils).
- Malone, Mrs. Elsie, 1017 Periwinkle Way, Box 54, Sanibel Island, FL. 33957 (Buy, sell, exchange world shells).
- Marshall, Dr. Donald S., Far Lands House, 3414 Halcyon Dr., Alexandria, VA. 22305.
- Marshall, Mrs. Thomas H., 2237 N.E. 175th St., Seattle, WA. 98155 (World shells; exchange).
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- Mastenbroek, Paul W., P.O. Box 67, Woodbridge, Ontario L4L 1A9, Canada (Distribution and systematics, Northern North Atlantic Ocean and adjacent seas).
- Mathiak, Mr. and Mrs. Harold A., 209 S. Finch St., Horicon, WI. 53032 (History of Wisconsin mussels; species distribution).
- Mazurkiewicz, Michael, Associate Prof. of Biology, Depart. Biological Sciences, Univ. of Maine at Portland-Gorham, 96 Falmouth St., Portland, ME. 04103 (Larval development and ecology of estuarine mollusks).
- McCaleb, John E., Highland Garden Apts., Bldg. E, Apt. B-5, 850 Schuyl Kill Rd., Pottstown, PA. 19464 (Freshwater mollusks of N.A., esp. *Pleuroceridae*).
- McCallum, Mr. and Mrs. John, 4960 Gulf of Mexico Dr., Apt. PH6, Sarasota, FL. 33577.
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- McInnes, Mrs. Comelia G., F-6 Raleigh Apts., Raleigh, NC. 27605 (All Marine).
- McLean, Dr. James H., Los Angeles County Museum, 900 Exposition Blvd., Los Angeles, CA. 90007.
- McRae, Mrs. Catherine, 903 King's Crown Dr., Sannibel, FL. 33957 (*Pectinidae*).
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- Menzel, Dr. R.W., Dept. of Oceanography, Florida State Univ., Tallahassee, FL. 32306 (*Oysters; clams*).
- Merrill, Arthur and Harriet, 16 Fisherman's Cove Road, E. Falmouth, MA. 02536.
- Merritt, Jack H., 2281 Euclid Ave., Ft. Myers, FL. 33901.
- Metcalf, Dr. Artie L., Dept. of Biology, Univ. of Texas at El Paso, El Paso, TX. 79968 (*Terrestrial Gastropoda of S.W. U.S.*).
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- Middelsen, Paul and Paula, 326 Circle Ave., TRL. H, Melbourne, FL. 32935 (*Donacidae*).
- Miles, Dr. Charles D., 6325 West 73rd Terrace, Overland Park, KS. 66204.
- Miller, Barry B., Dept. of Geology, Kent State Univ., Kent, OH. 44242 (*Non-marine Pleistocene, Malacology*).
- Miller, Fontelle, 685 17th Ave. S., Naples, FL. 33940 (*Astraeinae*).
- Miller, Dr. Walter B., 6140 Cerrada El Ocote, Tucson, AZ. 85718.
- Miser, Wendel L., 6562 Gildor St., Alexandria, VA. 22310 (*Fresh water mollusks*).
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- Moia, Marcela, O'Higgins 2057, piso 8 A, Buenos Aires, Argentina (*South American, Argentina general*).
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- Morrison, Robert W., 5111-H Ocean Blvd., Sarasota, FL. 33581 (*Cyprae, Voluta, Oliva, Murex*).
- Mousley, Louis B., 35350 Panorama Dr., Yucaipa, CA. 92399.
- Moyer, Edward J., 1605 S. Henderson, Fort Worth, TX. 76104 (*Indo-Pacific, Gulf of Mex.*).
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- Murray, Dr. Harold D., Biology Dept., Trinity Univ., San Antonio, TX. 78284 (*Unionidae; distribution and parasites*).
- Murray, Mr. and Mrs. Talbot E. Jr., Grad. Sch. of Oceanography Univ. of R.I., Narragansett, RI. 02882.
- Musick, Mrs. John W. and Richard M. Musick, 1238 E. Bayshore Dr., Virginia Beach, VA. 23451 (*Shell collecting for profit*).
- Myer, Dr. Donald G., Dept. of Biological Science, Southern Illinois Univ. at Edwardsville, IL. 62025 (*Land snails*).
- Naide, Dr. Meyer, 2034 Spruce St., Philadelphia, PA. 19103.
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- Nicol, Dr. David, P.O. Box 14376, University Station, Gainesville, FL. 32604.
- Nicolaci, Mr. and Mrs. Domenick, Bella Vista Is., Box 147, Fairhaven, MA. 02719 (*Pecten; exchange*).
- Nielsen, Richard L., Box 278, Fletcher Academy, Fletcher, NC. 28732 (*Non-marine aquatic mollusks*).
- Noseworthy, Ronald G., P.O. Box 104, 41 Main St., Grand Bank, Newfoundland, Canada AOE 1W0 (*North Am. circum-boreal mollusks; also Clausiliidae and Turridae*).
- Notter, Miss Helen, 2529 Gilmore St., Jacksonville, FL. 32204.
- Nowell-Usticke, Gordon, 1 North St., Christiansted, St. Croix, Virgin Islands 00820.
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- Oatis, Bona D., 312 Holiday Park Dr., Pittsburgh, PA. 15239 (*World marines; exchange*).
- Ode, Dr. Helmer, 4811 Braeburn Dr., Bellaire, TX. 77401 (*Gulf of Mexico marines*).
- Oesch, D. Ronald, 9 Hill Dr., Glendale, MO. 63122 (*Missouri mussel zoogeography*).
- Oetzell, Miss Edith M., 518 S. Ardmore Ave., Villa Park, IL. 60181 (*Conus*).
- Old, William E. Jr., Dept. of Mollusks, American Museum of Natural History, Central Park W. and 79th St., New York, NY. 10024.
- Olsen, Philip L., 10708 Blossom Lane, Silver Spring, MD. 20903 (*Cape Hatteras to Cape Cod mollusks*).
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- Papp, Mrs. Zoltan, Schnecksville, PA. 18178.
- Parmalee, Dr. Paul W., Prof. of Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916 (*Freshwater mollusks from archaeological sites*).

- Parodiz, Dr. Juan Jose and Esther, Sect. of Invertebrates, Carnegie Museum, 4400 Forbes Ave., Pittsburgh, PA. 15213 (Neotropical mollusks and freshwater Gastropoda of USA).
- Patch, Dianna Craig, 1376 Hamlet, Apt. B., Columbus, OH. 43201 (Grad student in Anthropology, OSU).
- Paul, A.J., Seward Marine Station, Institute of Marine Science, Box 617, Seward, AK. 99664 (Biology of commercially harvested Gastropods of Bering Sea, esp. *Neptunea pribiloffensis*).
- Pearson, Kermit, Gloria, and Eric, Box 1002, APO, San Francisco, CA. 96555 (Kwajalein Kwajalein Island, Missile Range, interested in exchange).
- Penchaszadeh, Dr. Pablo E., Universidad Simon Bolivar, Instituto de Tecnologia y Ciencias Marinas, Caracas, Venezuela.
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- Peyton, Gary, 810 Rose, Denton, TX. 76201 (Environmental chemist; int. in effect of chemical pollutants on mollusks).
- Phillips, Ted, 4580 Nueces Dr., Santa Barbara, CA. 93110.
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- Piper, Mr. and Mrs. Emmitt H., P.O. Box 85, Gloucester, N.C. 28528.
- Piplani, Shirley A., 26 Jameson Place, West Caldwell, NJ. 07006 (Chitons).
- Plockelman, Cynthia H., 311 Franklin Rd., West Palm Beach, FL. 33405 (Caribbean Muricidae, Naticidae).
- Porter, Hugh J., 119 Fairway Rd., Morehead City, NC. 28557 (Systematics, culture of bivalves).
- Post, Mrs. Alfred P. Jr., P.O. Box 65, Darlington, MD. 21034.
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- Pratt, W.L. and Suzann Denton Pratt, Museum of Natural History, Univ. of Nevada, Las Vegas, 4505 Maryland Pkwy. S., Las Vegas, NV. 89154.
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- Putnam, Mrs. Judith Dorr, P.O. Box 1178, Ft. Collins, CO. 80521 (Sphaeriidae).
- Quammen, Mrs. Delbert J., 402 Homestead Rd., Strafford-Wayne, PA. 19087.
- Queen, Loma B. (Mrs. C.B.), Rt. 1 Box, Pollocksville, N.C. 28573 (Mollusks of the Southeast Atlantic).
- Racela, Dr. Antonio Jr. and Dr. Luz Racela, 126 W. 116th St., Kansas City, MO. 64114 (Philippine land and marine shells).
- Raeihle, Dorothy and George, 211 Milligan Rd., West Babylon, NY. 11704.
- Raup, Timothy A., 910 Farrell Ave., Kalamazoo, MI. 49007 (Conus).
- Ravalli, Rose, 433 Dogwood Ave., West Hempstead, NY. 11552.
- Raymond, Torrance C., 99 Ridgeview Rd., Poughkeepsie, NY. 12603.
- Reader, Mr. and Mrs. William R., 4772 49th Ave. North, St. Petersburg, FL. 33714 (Live mollusks).
- Reeder, Richard L., Faculty of Nat. Sci., Univ. of Tulsa, Tulsa, OK. 74104 (Land pulmonates).
- Rehder, Dr. Harald A. and Lois C., 5620 Ogden Rd., Washington, DC. 20016.
- Rhode, Homer J., 977 Botany Lane, Rockledge, FL. 32955 (Marine collecting).
- Rice, Thomas C., Of Sea and Shore Publications, P.O. Box 33, Port Gamble, WA. 98364 (Dealer).
- Richards, Charles S., Lab. of Parasitic Diseases, National Institute of Health, Bethesda, MD. 20014 (Freshwater mollusks, host-parasite relations, mollusk pathology and genetics).
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- Roworth, Edwin C., 1361 Windsor Rd., Cardiff-by-the-Sea, CA. 92007 (World shells and sea life).
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- Stern, Dr. Edward M., Dept. of Biology, Univ. of Wisconsin-Stevens Point, Stevens Point, WI. 54481 (Systematics and ecology of terrestrial gastropods and Unionidae).
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HOW TO STUDY AND COLLECT SHELLS, latest edition of the popular symposium published by the American Malacological Union, may be purchased for \$2.50 each from Paul Jennewein, Corresponding Secretary, Box 394, Wrightsville Beach, NC.28480. Regular bookseller's discounts are available for purchase of copies of 10 to 50 copies.

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**BULLETIN OF
THE AMERICAN
MALACOLOGICAL
UNION**

for 1978

**COVERING THE
FORTY FOURTH
ANNUAL MEETING**

**Wilmington,
North Carolina**

July 16 - 21, 1978



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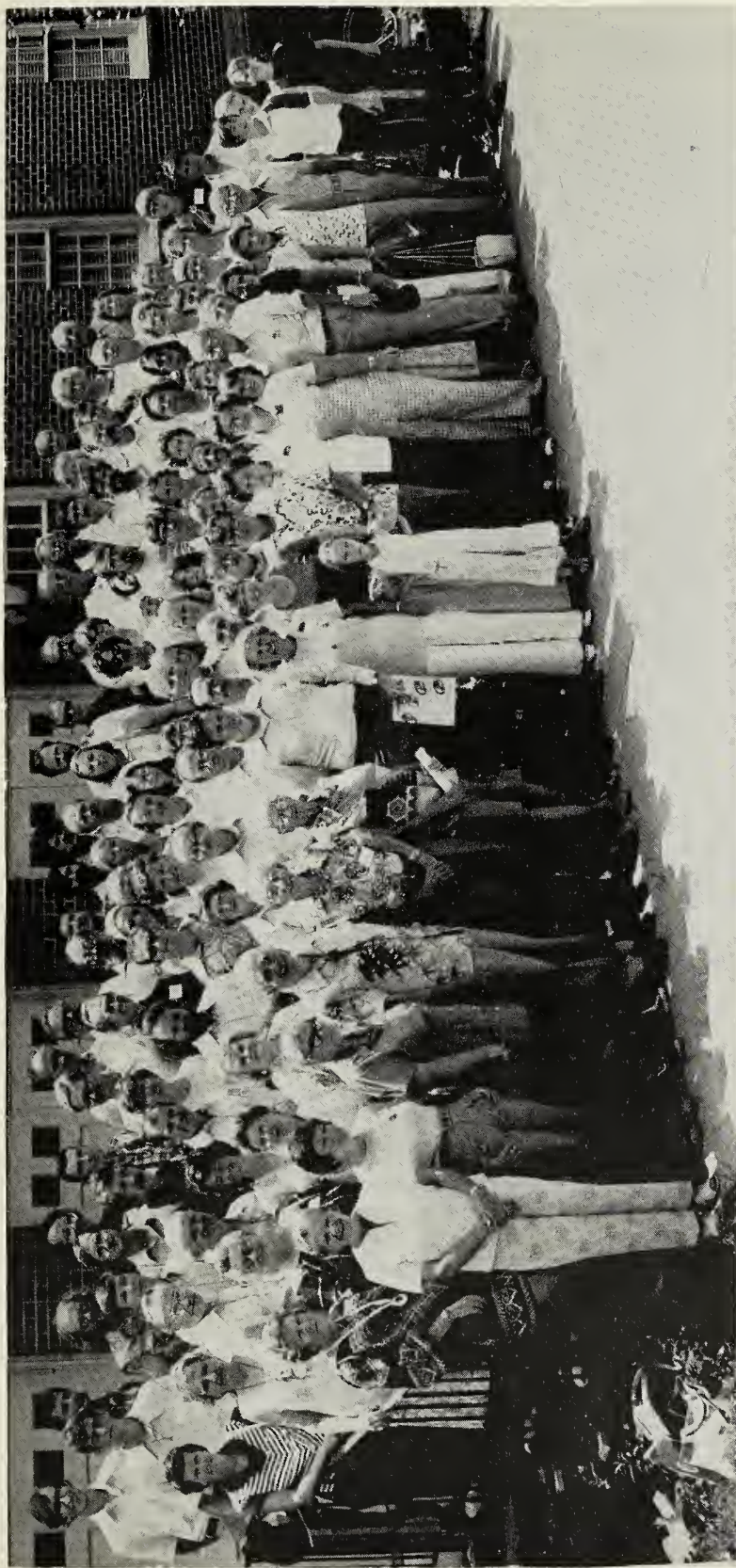
for 1978

**COVERING THE
FORTY FOURTH
ANNUAL MEETING**

**Wilmington,
North Carolina**

July 16 - 21, 1978





AMU'78 — Wilmington, North Carolina

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AMERICAN MALACOLOGICAL UNION, INC.
Forty-Fourth Annual Meeting

July 16,-21, 1978
Wilmington, North Carolina

The Forty-Fourth Annual Meeting of the American Malacological Union was held July 16-21, 1978, on the campus of the University of North Carolina at Wilmington, North Carolina. It was back to college for most of the 107 registrants who were housed in a typical dormitory and who trekked back and forth to the cafeteria on campus and to the auditorium for sessions.

Registration on Sunday dawned with heavy rains which continued throughout the day and finally forced the evening Shrimperoo get-together indoors.

Formal sessions started on Monday. The sun shone. Members headed for King Hall (the University called this the Child Study Center) at 2 p.m. where President Carol B. Stein opened the program. Paul R. Jennewein, co-chairman of the local committee, welcomed everyone and introduced William H. Wagoner, chancellor of the University of North Carolina at Wilmington, for more greetings. Mary Mobley, president of that state club hosting this meeting, extended her wishes for a fine meeting and promised well-known Southern hospitality which we all enjoyed throughout the week.

Papers that afternoon concerned fresh water mussels. Jeanne Whiteside chaired a lively conservation committee meeting later that afternoon where a number of resolutions was adopted to be submitted to Council.

A mini-symposium "The Hows, Whys, and Wherefores of Building a Scientifically Valuable Mollusk Collection," held on Monday night and brought out a crowd of registrants and local shellers. Dr. R. Tucker Abbott, Dr. David Stansbery, and Mr. W. Lloyd Pratt demonstrated and discussed methods used in museums. Mr. H. Wallace Roberts made it clear that donations to museums are tax deductible.

Tuesday's sessions were brimful with papers on many phases of the study of mollusks. Shell club night, chaired by Hugh J. Porter, co-chairman of the local committee, included slides of travels, slides of former meetings, reports from clubs and provided time for shellers to visit. This is always a highlight of the meeting.

The papers on Wednesday ranged from research reports on South African land snails to a review of mollusks from Fort Macon, N.C., to a discussion and slide presentation of endemic marine gastropods of Brazil, discussed by our Brazilian member, Dr. E.C. Rios.

Gilbert W. Bane, professor of marine sciences of the University of North Carolina at Wilmington, entertained members Wednesday night by talking on sharks and rays and giving cooked shark tidbits to everyone present including Council members who were meeting elsewhere.

The last session of papers was held on Thursday morning, that afternoon the general business meeting was held and officers were elected and important resolutions adopted.

Angelo's Italian Village was reached by bus and car that evening for "attitude adjustment period" and a fine banquet. Dr. William J. Clench, as banquet speaker, delighted everyone with the AMU "memory lane" slides and movies. Dr. Clench's intimate knowledge of the history of AMU and his special interest in Archives came through loud and clear as we joined him in viewing early scenes of AMU gatherings and chuckling at seeing members in years past. Most of us had heard all about the romance of members Bunny and Horace Baker, but seeing Tucker Abbott spread flower petals on that path of love can't be described — you simply had to see this action! Thank you Bill for sharing all of this with all of us.

Dr. Stein introduced the large number of past presidents in attendance, acknowledged the local committee workers who had arranged for all the good times, and finally turned the gavel over to new president William E. Old, Jr.

Friday was a gorgeous day, just right for the number of field trips offered registrants — bay collecting, fossiling, canoeing, digging for clams in Lake Waccamaw. Once again AMU members straggled back muddy and wet, happy with their collections. The meeting was officially over, but discussion went on and on that evening at several dining places as members compared collections and made plans for future meetings.

There really is a uniqueness to every AMU meeting. One member wrote that this meeting brought back memories of some of the earlier meetings he remembers with pleasure also. The opportunity offered each year for professional and amateur members to enjoy each other is evident each meeting.

Mark Aug. 5-11, 1979, on the calendar and come to Corpus Christi, Texas, for the joint meeting with the Western Society of Malacologists. Y'all come, you heah!

Constance E. Boone

well as calcite-aragonite differentiation methods outlined by Schneidermann and Sandberg (1971).

RESULTS AND DISCUSSION

From the periostracum inwards, calcified structural layers of the mature *G. demissa* shell consist of: (1) blocky calcite (Fig. 1A, B); (2) prismatic aragonite (Fig. 1A-C); (3) nacre (Fig. 1A, C); (4) prismatic aragonite (pallial myostracum); and (5) alternating sub-layers of aragonitic prisms (and, occasionally, homogeneous structures) and nacre (Fig. 1D). This description differs markedly from that presented by Blackwell *et al* (1977). Discrepancies between our own observations and those of Blackwell *et al* (1977) result primarily from the fact that the latter workers only examined sections from portions of the shell outside the pallial line (L.F. Gainey, Jr. and M.J. Greenberg, personal communication). As a result, neither the relatively prominent pallial myostracum, nor the extensive inner shell layer, with its alternating sub-layers, were observed. A further discrepancy arises regarding the structure of the outermost shell layer. Blackwell *et al* (1977) describe the structure of this calcitic layer as prismatic, while reporting that the ultrastructure of this layer "could not be observed in stained, polished sections examined with the SEM." In recent shell structure literature (Kennedy *et al*, 1969; Taylor *et al*, 1970) the term "prismatic" has a relatively specific connotation. No evidence is presented by Blackwell *et al* (1977) to warrant the employment of this term to describe the structure of the outermost shell layer. The ultrastructural appearance of this layer, as seen in Figure 1 B, renders the term "blocky calcite" far more appropriate than "prismatic."

The thickness of the shell layers outside of

and including the pallial myostracum gradually increases from the umbonal region to the posterior margin. As a result of this observation, the relatively constant shell layer thicknesses reported by Blackwell *et al* (1977) are considered misleading, if not inaccurate.

Page 5

Anodonta grandis forma *grandis* Say, 1829. Specimens occurred at all collecting sites but were abundant in the upper portions of the lake.

Anodonta grandis forma *stewartiana* Lea, 1834. Valentine and Stansbery (1971) placed *stewartiana* as a form of *A. grandis*. This may be correct, but I observed no integrades of the form *grandis* with the form *stewartiana* in this lake. Murray (1972) reported the same situation in Lake LBJ, Texas and indicated that the presence of these two forms in the same localities of a lake with no integrades required further consideration of this taxonomic relationship. Both forms *grandis* and *stewartiana* are common in Lake Corpus Christi.

Anodonta imbecilis Say, 1829. *A. imbecilis* was common at sites I and IV and rare at sites II and III.

Cyrtonaias tampicoensis (Lea, 1838). This is *Lampsilis tampicoensis* Lea as listed by Strecker (1931). In Texas, this species is highly variable in

CONTRIBUTED PAPERS PRESENTED AT THE 1978 MEETING

FRESHWATER MUSSELS OF LAKE CORPUS CHRISTI, TEXAS

Harold D. Murray
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Lake Corpus Christi is located approximately 48 km from Corpus Christi, Texas on the lower portion of the Nueces River which is about 491 km in length. At normal level the lake is 28.7 m above sea level and has a surface area of 9.6 ha. The lake occupies portions of Jim Wells, Live Oak, and San Patricio counties and is the freshwater supply for Alice and Corpus Christi, Texas. A recent drought lowered the lake to 25 m above sea level and exposed large areas of the lake bed which were extensively collected at four sites on October 22, 1977. Location of collection sites are given as distance from the dam-site I, 3.2 km; site II, 7.2 km; site III, 11.3 km; site IV, 23.3 km. Habitats varied from the steep banks with hard substrate at site I near the dam to gently sloping lake bed of soft mud at site IV. All species were collected alive.

The most recent and complete study of naiads of Texas was by Strecker (1931) who listed nine species and subspecies for the Nueces River; however, none of his records includes the counties in which the lake occurs. The following list is the first published record of bivalves of the lower portion of the Nueces River.

Anodonta grandis forma *stewartiana* Lea, 1834. Specimens occurred at all collecting sites but were abundant in the upper portions of the lake.

Anodonta grandis forma *stewartiana* Lea, 1834. Valentine and Stansbery (1971) placed *stewartiana* as a form of *A. grandis*. This may be correct, but I observed no integrades of the form *grandis* with the form *stewartiana* in this lake. Murray (1972) reported the same situation in Lake LBJ, Texas and indicated that the presence of these two forms in the same localities of a lake with no integrades required further consideration of this taxonomic relationship. Both forms *grandis* and *stewartiana* are common in Lake Corpus Christi.

Anodonta imbecilis Say, 1829. *A. imbecilis* was common at sites I and IV and rare at sites II and III.

Cyrtonaias tampicoensis (Lea, 1838). This is *Lampsilis tampicoensis* Lea as listed by Strecker (1931). In Texas, this species is highly variable in

shell size, color of nacre, and color of periostracum. The deep purple nacre of specimens from Lake Corpus Christi resembles specimens from Lake LBJ, Texas, but Lake Corpus Christi specimens have a light to dark brown periostracum unlike specimens from Lake LBJ which are black (Murray, 1972). This species was abundant at all sites except III where it was rare.

Lampsilis anodontoides (Lea, 1834). This species was rare at site III, common at sites I and II, and abundant at site IV.

Lampsilis hydiana (Lea, 1838). This species is judged as rare in Lake Corpus Christi as only one live animal and one valve were collected in the soft mud of site III.

Quadrula aurea (Lea, 1859). The author is unsure of this identification based on the one live specimen obtained. In general, it conforms to the descriptions by Strecker (1931) and Simpson (1914). Two specimens were obtained from the soft mud of site III.

Quadrula quadrula (Rafinesque, 1820). As was the case with this species from Lake LBJ (Murray, 1972), all *Q. quadrula* from Lake Corpus Christi are highly pustulose on the umbo and over the lateral, anterior, and posterior surfaces of the shells. Pustule formation ceases as the shell length reaches about 55mm, and as it continues to grow, the shell more closely resembles this species from the Mississippi drainage. *Q. quadrula* was common at all sites except III.

Toxolasma (= *Carunculina*) *parva* (Barnes, 1823). Numerous specimens measuring up to 55mm shell length occurred at all collecting sites except III. This population of large specimens having highly inflated umbos is probably what Strecker (1931) referred to as *C.p. mearnsi* (Simpson, 1900) which he recorded for south and west Texas.

Corbicula manilensis (Philippi, 1841). The first specimens of *C. manilensis* from Lake Corpus Christi (Lake Mathis) were obtained in August,

1969 (Murray, 1971). *C. manilensis* was rare in 1969 but occurred at all sites of this study. The presence of large members of living *C. manilensis* in the shallow water of site III where only 12 living unionids were obtained in association with hundreds of dead unionids suggests that *C. manilensis* is displacing the native unionids of the site.

At present, Lake Corpus Christi has nine species of the family Unionidae and one species of the family Corbiculidae. Surprisingly, there are no representatives of the genus *Amblema* in the lake. *Amblema* is a genus common to lakes and rivers in central and south Texas and was recorded in the Nueces River by Strecker (1931). Absence of *Amblema* from the lake is not due to the absence of host fish. Both the white crappie, *Pomoxis annularis*, and the black crappie, *P. nigromaculatus*, occur in the lake and both are recorded as hosts for *Amblema* glochidia (Baker, 1928). No explanations for the absence of *Amblema* is here offered. The other species record-

ed by Strecker (1931) in the Nueces River but absent from this study was *Ligumia subrostrata* (Say).

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LARVAL GROWTH IN FINGERNAIL AND PILL CLAMS (BIVALVIA: SPHAERIIDAE)

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INTRODUCTION

The importance of sphaeriid clams as food items for many commercially and economically important species of fish and waterfowl and the use of some fingernail clams as test animals in toxicity bioassays has stimulated inquiries into the life histories of these ovoviviparous clams. However, in spite of the large amount of literature on various life history aspects of Sphaeriidae (see Heard, 1977 for a review of these life history studies), only a few examine development of larval stages and none examine larval growth dynamics.

The present study determines the growth of larvae in relation to that of parents in species of *Sphaerium* and *Musculium* that have several ontogenetic larval stages and in species of *Pisidium* that have only one ontogenetic larval stage in any one parent. The study also examines seasonal variations in the sizes of broods in different stages of development.

MATERIALS AND METHODS

Five, locally abundant species were examined: *Sphaerium fabale* from the Eramosa River; *Musculi-*

um lacustre from a permanent pond on Waterloo Avenue in Guelph, Ontario, and from a permanent pond in Kortright Waterfowl Reserve near Guelph; *Musculium securis* from a temporary pond on Clair Road south of Guelph; *Pisidium casertanum* from a temporary roadside pond on Wellington Road 32, and a temporary pool off Hanlon Creek near Guelph; *Pisidium variabile* from a permanent pond in the Kortright Waterfowl Reserve. Data obtained for *M. securis* in Carp Pond, Greely Pond, Britannia Bay, and Lac Bourgeois (see Mackie, Qadri and Clarke 1976a, 1976b for life history aspects and descriptions of these habitats) were also used in this study.

Life history collections were made at least twice a month in the summer and once a month in the winter using a sieve with 0.32 mm openings. Usually 30-100 clams were collected and isolated into vials, to retain any extra-marsupial larvae that may have been aborted in transit to the laboratory, and preserved in 70% ethanol.

After measuring shell length of adults on a Wild Stereomicroscope equipped with an ocular vernier scale, each adult was dissected and the fetal larvae,

prodissoconch larvae, and extra-marsupial larvae enumerated. The lengths of the shell on all shelled larvae were also determined with the ocular vernier scale. The presence of embryos in each parent was noted but their numbers were not recorded. The classification of the four ontogenetic stages of larval development follows that described by Heard (1977).

Growth rates were determined during the log phase of growth of adults as determined from most common length-classes in length-frequency histograms (not included this paper). Usually the log phase occurred for a four to six week period. Since growth is linear at this time, a linear regression (i.e., $y = a + bx$) was used and differences were determined by comparing regression coefficients (i.e., b = growth rate) using the test of homogeneity of two b 's (Steel and Torrie, 1960). Some larvae in each sac often showed retarded growth (i.e. shell length was only about one half that of most other larvae in same sac) but since retarded larvae do not complete development (Meier-Brook, 1977) they were not used in calculations for larval growth rates. Regressions of individual larval length on individual parent length were also calculated to assess relative growth rates of larvae and adults; rates (regression coefficient, b) greater than 1.0 indicate that larvae grow faster than parents, less than 1.0 indicate that parents grow faster than larvae and if equal to 1.0 both larvae and adults grow at the same rate. 95% confidence intervals were calculated for " b " values to determine if regression coefficients were significantly greater or less than 1.0.

RESULTS AND DISCUSSION

Life histories

Table 1 summarizes the birth periods, longevities and the length classes of parents in which each larval stage first appears. Individuals of most species die after producing one litter of young and only *M. securis* produces as many as three litters before the parents die. Similar life history data has been obtained elsewhere for the same species and a review of these studies is given in Heard (1977).

Larval Growth

Fig. 1 shows that larvae of all species stop growing and are of birth size when parents cease to grow. Table 2 shows that larvae grow slower than parents (i.e., $b < 1.00$) in all populations of *M. lacustre*, *P. casertanum* and *P. variabile*, as fast as parents (i.e., $b = 1.00$) in *S. fabale* and as fast or faster than parents

(i.e., $b \leq 1.00$) in *M. securis*. These results imply that the only larvae to be born are those that have matured to the extra-marsupial stage by the time the adult stops growing and all other larval stages may perish. Implicit in this interpretation is the production of only one litter of young (i.e. semelparity) and iteroparity occurs only if (a) there is precocious (early) birth of extra-marsupial larvae, (b) growth rates of larvae exceed those of parents, or (c) there is precocious birth of rapidly growing larvae [i.e. a combination of (a) and (b).]

In *S. fabale*, larvae grow at approximately the same rate as adults indicating that production of more than one litter occurs mainly by precocious birth of extra-marsupial larvae. In the Eramosa River population, the average length of newborn and extra-marsupial larvae in P₁ parents is 5.20 mm and 4.55 mm, respectively, and the shortest newborn is 2.93 mm, indicating some precocious births from smaller P₂ parents. However, the lengths of extra-marsupial larvae within a single parent occasionally range by 2.00 mm suggesting that the smallest newborn may be from the same litter as the largest newborn. Also, some larvae may grow faster than the average larvae and a small percentage may produce two litters through accelerated growth of larvae. Since there are as many as three overlapping generations, it is difficult to prove which mechanism is used to produce extra litters, if any are produced.

In *M. lacustre*, growth rates of larvae are only about two fifths that of parents, indicating that production of more than one litter can only occur by precocious births of extra-marsupial larvae. Analyses of larvae in brood sacs from sequential parents in both populations (Mackie, Qadri and Clarke 1976b) indicate that only one litter is produced. Also, the absence of newborn significantly shorter than 1.36 mm in Waterloo pond and 1.02 mm in Kortright Pond (the shortest of first litter extra-marsupial larvae) suggests that no precocious births occur in either population of *M. lacustre* where average lengths of newborn are 1.78 mm and 1.33 mm, respectively.

In *M. securis*, growth rates of larvae are the same as or greater than that of parents. This implies that more than one litter is produced by *M. securis*. Fig. 2 shows that the percentage of each population that produces two litters increases as the regression coefficient of larval length on adult length (from Table 2) increases.

In both *P. casertanum* and *P. variabile*, larvae grow slower than adults indicating that extra litters

TABLE 1

Birth periods, longevities and length classes (mm) of parents in which each larval stage first appears for eleven populations of sphaeriid clams.

Species and population	Birth Periods	Longevity (months)	Length classes of parents with first appearance of			
			Embryos	Fetal larvae	Prodissoconch larvae	Extra-marsupial larvae
<i>Sphaerium fabale</i> , Eramosa River	early summer & late fall	12-15	6.5-7.5	7.0-8.0	7.5-8.5	8.5-9.5
<i>Musculium lacustre</i> , Waterloo Pond	July to August	6-12	1.5-2.0	2.5-3.0	4.0-4.5	5.0-5.5
<i>M. lacustre</i> , Kortright Pond	fall to spring	12	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5
<i>Musculium securis</i> , Clair Road	early summer	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>M. securis</i> , Carp Pond 1970	early summer	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>M. securis</i> , Carp Pond 1971	early summer	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>M. securis</i> , Carp Pond 1972	early summer	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>M. securis</i> , Greely Pond	early summer	12	2.0-3.0	3.0-4.0	4.0-5.0	4.5-5.0
<i>M. securis</i> , Britannia Bay 1971	mid summer & late fall	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>M. securis</i> , Lac Bourgeois	summer & fall	12	2.0-3.0	3.0-4.0	4.0-4.5	4.5-5.0
<i>Pisidium casertanum</i> , Roadside Pond	early summer	12	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0
<i>P. casertanum</i> , Hanlon Creek Pool	late spring & late summer	4-6	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5
<i>Pisidium variable</i> , Kortright Pond	summer	12	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0

TABLE 2

Linear regression data for logarithmic phase of growth of larval length (y) on adult length (x) (mm). All R values are significant at $P \leq 0.001$. N = sample size in each regression and S.E. = standard error of B estimate.

Species and Population	N	Y=A + BX		R	S.E.
		A	B		
<i>Sphaerium fabale</i> , Eramosa River	32	-6.98	0.98 ¹	0.92	0.077
<i>Musculium lacustre</i> , Waterloo Pond	30	-1.05	0.39 ²	0.96	0.022
<i>M. lacustre</i> , Kortright Pond	13	-0.89	0.38 ²	0.87	0.065
<i>Musculium securis</i> , Clair Road Pond	27	-3.41	1.05 ¹	0.87	0.121
<i>M. securis</i> , Carp Pond 1970	28	-3.52	0.96 ¹	0.92	0.089
<i>M. securis</i> , Carp Pond 1971	22	-5.23	1.41 ³	0.87	0.155
<i>M. securis</i> , Carp Pond 1972	12	-7.53	1.70 ³	0.88	0.297
<i>M. securis</i> , Greely Pond	26	-3.85	1.39 ³	0.94	0.072
<i>M. securis</i> , Britannia Bay 1971	17	-3.80	0.97 ¹	0.92	0.147
<i>M. securis</i> , Lac Bourgeois	18	-4.21	1.11 ¹	0.96	0.094
<i>Pisidium casertanum</i> , Roadside Pond	19	-1.60	0.58 ²	0.94	0.069
<i>P. casertanum</i> , Hanlon Creek Pool	17	-1.33	0.62 ²	0.81	0.055
<i>Pisidium variable</i> , Kortright Pond	17	-1.89	0.70 ²	0.82	0.078

¹ B not significantly different from 1.0

² B significantly less than 1.0

³ B significantly greater than 1.0

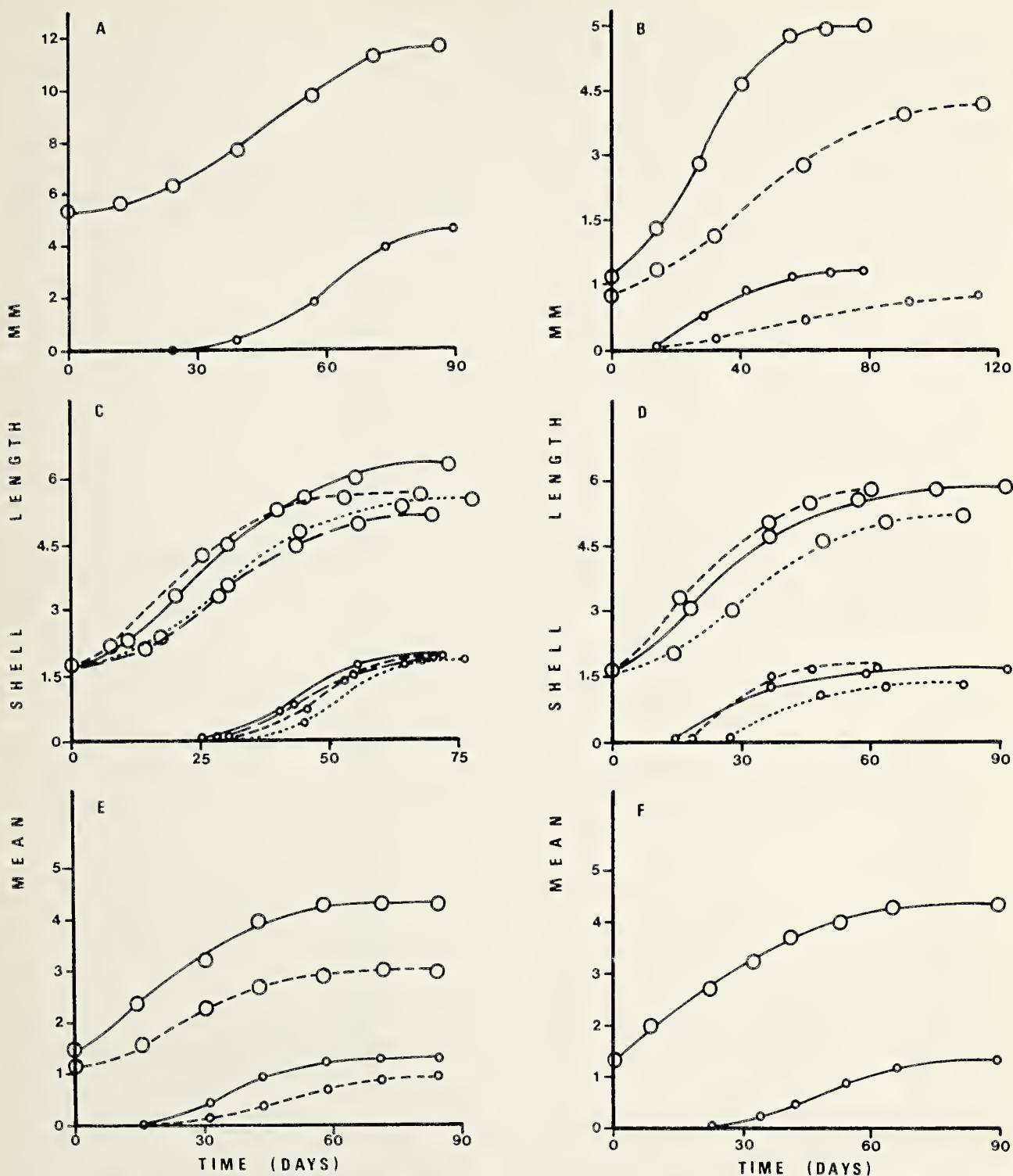


Fig. 1. Growth of one generation of parents (large circles) and larvae in first litters (small circles) of (A) *Sphaerium fabale* Eramosa River; (B) *Musculium lacustre*, Waterloo Ave. Pond (solid lines) and Kortright Pond (dashed lines); (C) *Musculium securis*, Carp Pond 1970 (solid lines), 1971 (dotted lines), 1972 (small dashes) and Clair Road Pond (large

dashes); (D) *Musculium securis*, Greely Pond (dashed lines), Lac Bourgeois (solid lines), and Britannia Bay (dotted lines); (E) *Pisidium casertanum*, Roadside Pond (solid lines) and Hanlon Pool (dashed lines); (F) *Pisidium variable*, Kortright Pond.

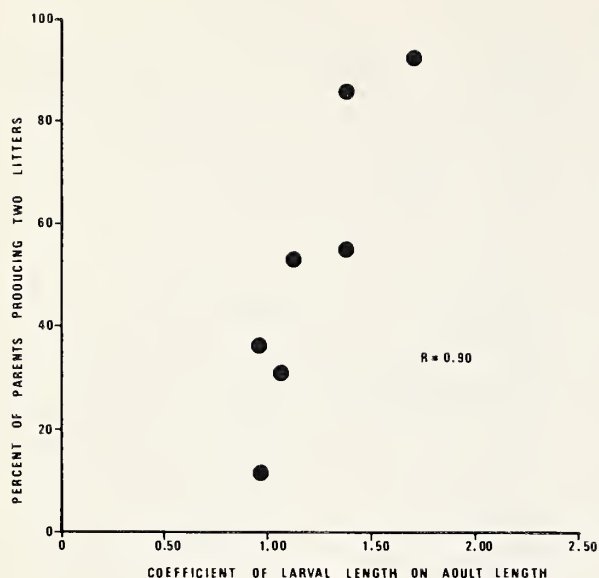


Fig. 2. Relation between percent of parents producing two litters and the coefficient (from Table 2) of larval length on parent length for *Musculium securis*. Correlation coefficient, R , is significant at $P \leq 0.02$.

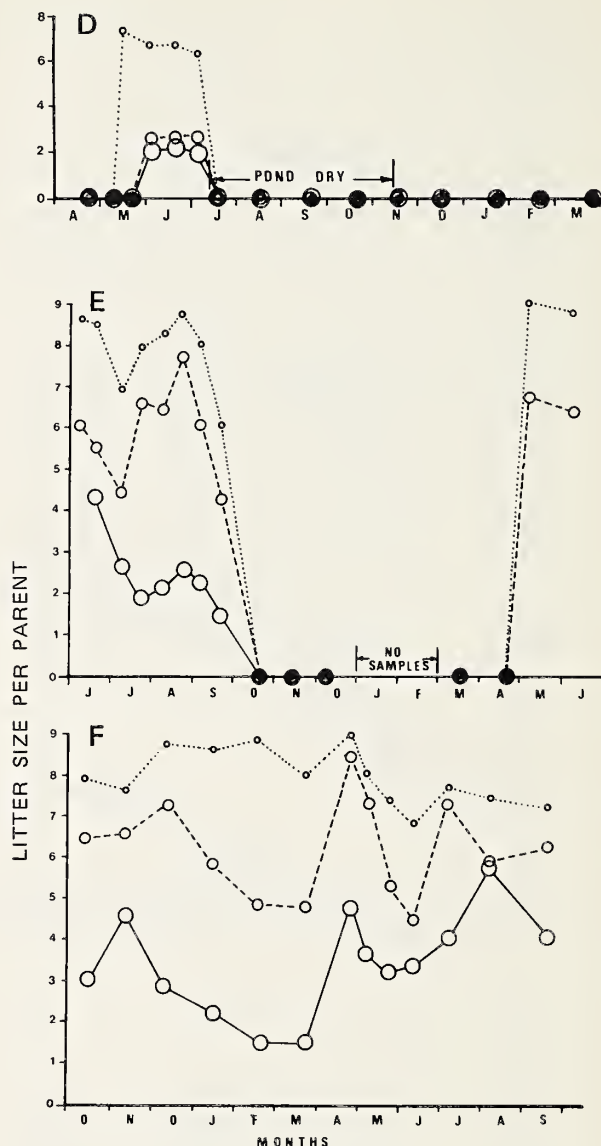
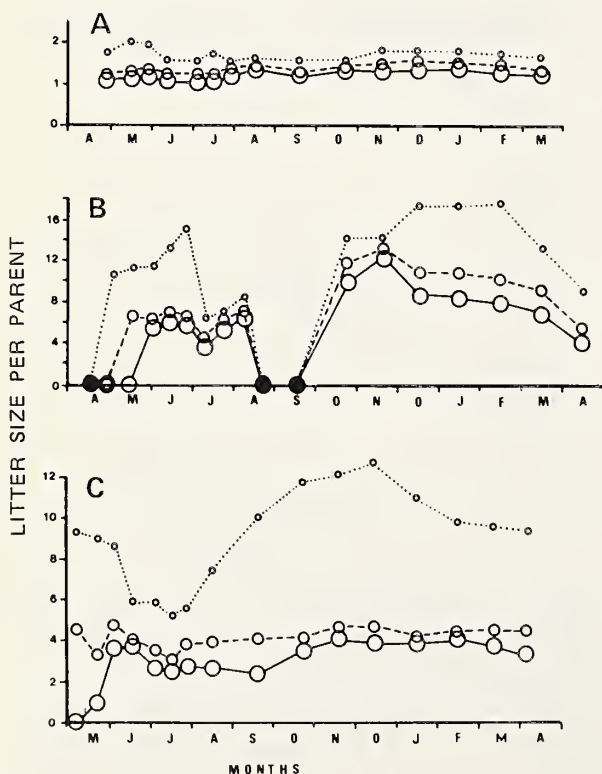


Fig. 3. Seasonal variations in sizes of litters at fetal (small circles), prodissococonch (medium circles), and extra-marsupial (large circles) stages for: (A) *Sphaerium fabale*, Eramosa River; (B) *Musculium lacustre*, Waterloo Ave. Pond and (C) Kortright Pond; (D) *Musculium securis*, Clair Road Pond, (E) Greely Pond, (F) Lac Bourgeois, (G) Britannia Bay, and (H) Carp Pond; (I) *Pisidium casertanum*, Hanlon Creek Pool, and (J) Roadside Pond, and (K) *Pisidium variable*, Kortright Pond. P1 and P2 in I and J indicate numbers of fetal larvae in first generation and second generation parents, respectively.

Fig. 3 continued on pages 11 and 12.

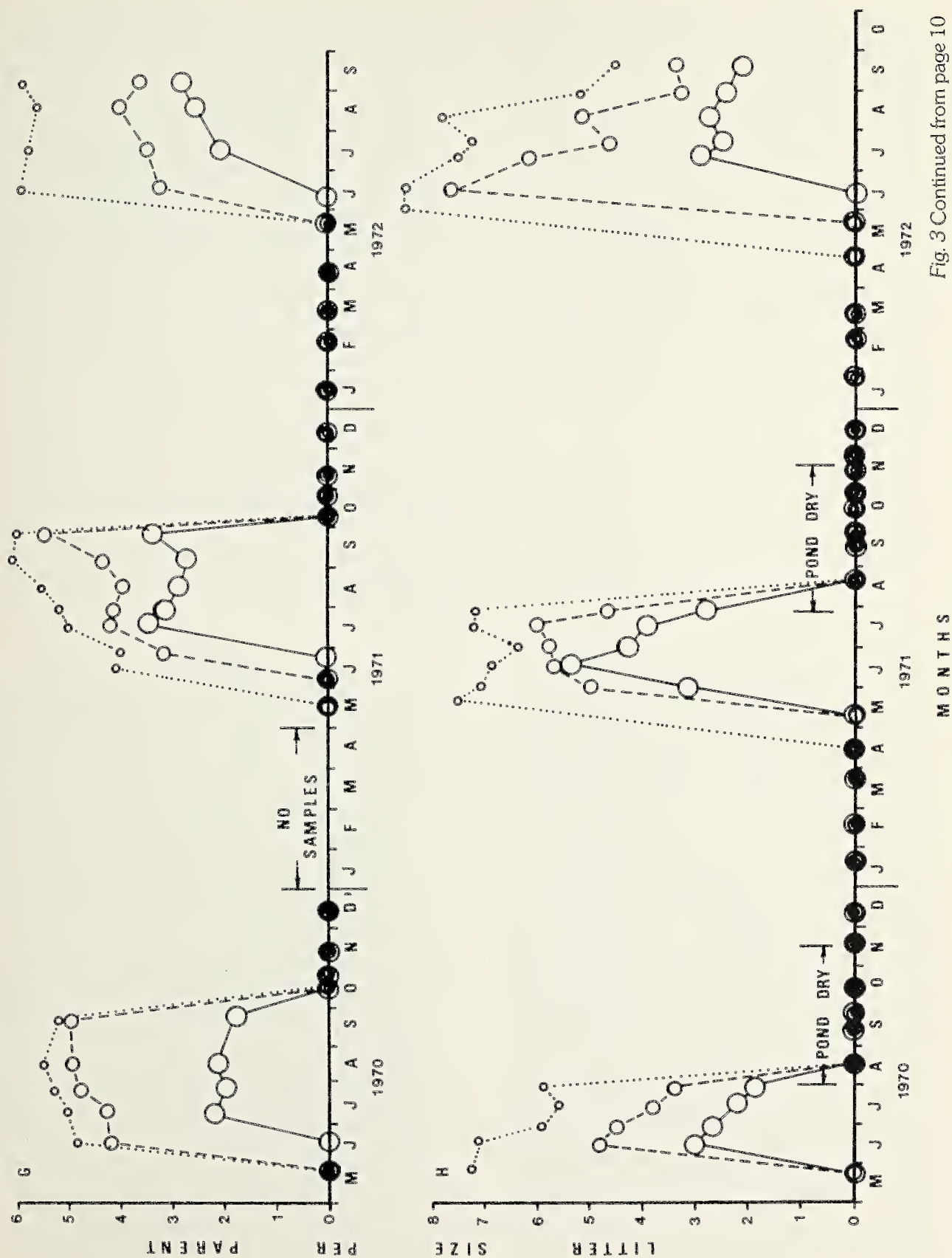


Fig. 3 Continued from page 10

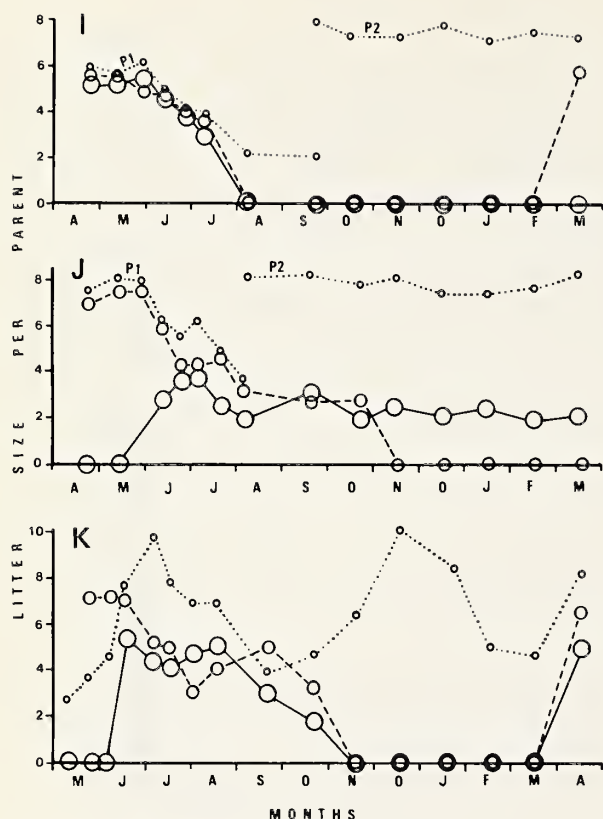


Fig. 3 continued from page 11

from one generation may be produced only by precocious births. However, analyses of the data show that both species produce one litter only (i.e. are semelparous) and then the parents die. Nevertheless, two or more litters may be produced within the population by producing two or more generations, each with only one litter. This requires rapid growth rates of parents. Most species of the subgenera, *Pisidium* s.s. and *Neopisidium* are iteroparous (Heard 1965) indicating that in such species larval growth rates either exceed parental growth rates, parents produce precocious young, or both of these. Additional studies are needed with such species to show which of these three mechanisms apply.

Seasonal Variations in Litter Sizes

Of the five species examined, *S. fabale* has the smallest litters at each larval stage. By back-calculation of brood-sacs in sequential parents, it is possible to determine mortality between each larval stage (Mackie, Qadri and Clarke 1976b). The greatest mortality occurs between the fetal and prodissococonch stages in all species, however, both *M. securis* and *M. lacustre* appear to have more mortality be-

tween prodissococonch and extramarsupial stages than other species examined (Fig. 3).

Most larval mortality occurs during the late winter months, presumably a phenomenon of "winter-kill," perhaps caused by a degradation in water quality (as indicated by high CO₂ content, low dissolved oxygen content, and low pH) in many habitats examined. A decline in numbers of larvae at each stage also occurs during the summer after a moderate spring increase for all species; this "summer-kill" may be due to a decline in available food resources, a degradation in water quality (as indicated by high temperatures and concomitant low dissolved oxygen contents) and/or senility of older and larger length classes in each generation. The causes of larval mortality are poorly understood and need considerable study.

Iteroparous "species" (e.g. *M. securis*, especially Carp Pond, Greely Pond and Lac Bourgeois populations) display greater larval mortalities than semelparous species (e.g. *M. lacustre*, *S. fabale*, *P. casertanum* and *P. variable*). However, only annual species were examined and similar studies are needed on species that live for two to three years to determine whether this observation, and others, still apply.

SUMMARY

- 1) Life history samples of *Sphaerium fabale*, *Musculium lacustre*, *Musculium securis*, *Pisidium casertanum* and *Pisidium variable* were collected at least monthly from ten different habitats.
- 2) Larval growth rates vary within species.
- 3) Regressions of larval length on parent length show that larvae grow slower than parents in *Musculium lacustre*, *Pisidium casertanum*, and *Pisidium variable*, as fast as parents in *Sphaerium fabale*, and as fast or faster than parents in *Musculium securis*.
- 4) Species with slow larval growth rates are usually semelparous and univoltine but can be iteroparous by precocious birth of larvae and multivoltine by accelerated growth of semelparous individuals.
- 5) Species with rapid larval growth rates are usually iteroparous because larvae grow faster than parents and/or there is precocious birth of larvae.
- 6) There is greater mortality of larvae during early stages than during later stages of development.
- 7) The greatest numbers of larvae per parent usually occur in early winter and/or late spring;

winter and summer "kills" often result in small litter sizes.

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SHELL STRUCTURE OF THE ATLANTIC RIBBED MUSSEL, *GEUKENSIA DEMISSA* (DILLWYN): A REEVALUATION

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INTRODUCTION

The Atlantic ribbed mussel, *Geukensia demissa*, inhabits brackish waters along the east coast of North America from the Gulf of St. Lawrence to Florida and along the Gulf coast from Florida to Yucatan (Abbott, 1974). Isolated populations have also been reported along the west coast as a result of the introduction of this species to San Francisco Bay (Hanna, 1966). The shell structure of the two reported subspecies, *G. d. demissa* and *G. d. granosissima*, has recently been compared and contrasted by Blackwell *et al* (1977). These workers report that the calcified portion of the mature shell of both subspecies is divided into three layers: (1) an innermost nacreous layer (approximately 1 mm thick) which comprises the major portion of the shell; (2) a middle aragonitic prismatic layer (0.1 mm thick); and (3) a thin (1 μ m) outer prismatic layer of calcite. In the present study, we offer a reevaluation of the shell structure of *G. demissa* based on detailed analyses of over 500 specimens from various geographical locations from Prince Edward Island to Florida.

MATERIALS AND METHODS

A total of 335 specimens of *Geukensia demissa* were sampled at monthly and, occasionally, biweek-

ly intervals over a 3-year period from both a natural intertidal population and an experimentally rafted population in the Damariscotta estuary, Lincoln County, Maine. In addition, 205 specimens were sampled during various times of the year from 12 geographically isolated populations from Prince Edward Island to Cape Kennedy, Florida. Shell lengths (maximum antero-posterior dimension) of sampled specimens varied from 5 to 103 mm. Organisms were collected during low tide, the adductor muscles severed, and soft tissues removed in the field, taking care not to damage inner shell layer growth surfaces. In the laboratory, the shells were gently rinsed under tap water and allowed to dry in air. Acetate peels (of polished and etched shell sections) or thin sections of one valve from each of the 540 specimens were prepared and examined using standard techniques (Pannella and MacClintock, 1968; Rhoads and Pannella, 1970). Selected fractured surfaces, polished and etched sections, and growth surfaces were coated (under vacuum) with gold-palladium or a combination of gold and carbon, and examined under several different scanning electron microscopes (Cambridge S-4, AMR-1000A, ETEC Autoscan). Mineralogical determinations were based on x-ray diffraction analyses, as

well as calcite-aragonite differentiation methods outlined by Schneidermann and Sandberg (1971).

RESULTS AND DISCUSSION

From the periostracum inwards, calcified structural layers of the mature *G. demissa* shell consist of: (1) blocky calcite (Fig. 1A, B); (2) prismatic aragonite (Fig. 1A-C); (3) nacre (Fig. 1A, C); (4) prismatic aragonite (pallial myostracum); and (5) alternating sub-layers of aragonitic prisms (and, occasionally, homogeneous structures) and nacre (Fig. 1D). This description differs markedly from that presented by Blackwell *et al* (1977). Discrepancies between our own observations and those of Blackwell *et al* (1977) result primarily from the fact that the latter workers only examined sections from portions of the shell outside the pallial line (L.F. Gainey, Jr. and M.J. Greenberg, personal communication). As a result, neither the relatively prominent pallial myostracum, nor the extensive inner shell layer, with its alternating sub-layers, were observed. A further discrepancy arises regarding the structure of the outermost shell layer. Blackwell *et al* (1977) describe the structure of this calcitic layer as prismatic, while reporting that the ultrastructure of this layer "could not be observed in stained, polished sections examined with the SEM." In recent shell structure literature (Kennedy *et al*, 1969; Taylor *et al*, 1970) the term "prismatic" has a relatively specific connotation. No evidence is presented by Blackwell *et al* (1977) to warrant the employment of this term to describe the structure of the outermost shell layer. The ultrastructural appearance of this layer, as seen in Figure 1 B, renders the term "blocky calcite" far more appropriate than "prismatic."

and including the pallial myostracum gradually increases from the umbonal region to the posterior margin. As a result of this observation, the relatively constant shell layer thicknesses reported by Blackwell *et al* (1977) are considered misleading, if not inaccurate.

The structure of the inner shell layer is dependent on both season of deposition and geographical location (Lutz, 1976, 1977; Lutz and Rhoads, 1977). The seasonal sequence of events occurring on the inner shell layer growth surface of specimens from the Damariscotta estuary, Maine, is summarized as follows. During the warm summer months (June through September), very regular hexagonal nacreous tablets are arranged in steplike patterns characteristic of bivalve nacre. As water temperatures decline, the nacreous tablets become smaller and less regular, showing visible signs of corrosion in the form of marked pitting and hollow crystals, as well as increased proportions of fine-grained structures [see Lutz and Rhoads (1977), Fig. 1 C]. A similar irregularity of nacreous crystals as a result of dissolution during reduced winter temperatures (as low as 8°C) was found by Wada (1972) in his examination of growth surfaces of *Pinctada martensii* and *Pinna attenuata*. During the colder months of the year (January to March, with water temperatures below 3°C), shell erosion becomes visible to the naked eye, the entire inner shell surface often presenting a chalky white appearance. Ultrastructurally, this surface appears uniformly fine-grained. Lutz and Rhoads (1977) have recently attributed this shell erosion to the buffering (with shell CaCO₃) of acidic end products from anaerobic metabolism during the colder months when oxygen transport into the cells should theoretically be reduced relative to that oc-

Figure 1. Scanning electron micrographs of vertical fractures through the shell of *Geukensia demissa*. The most recently deposited crystals are at the bottom of each of the micrographs. (A) Outer portion of shell approximately 2 cm posterior to the umbo (of a specimen with a length of 7 cm) depicting three calcified structural layers. The periostracum is seen at the top of the micrograph partially peeled away from the shell. From the periostracum (p) inwards, calcified structural layers consist of: (1) blocky calcite (bc); (2) irregular prismatic aragonite (pa); and (3) nacre (n). Scale bar represents 5 µm. (B) Outer portion of shell approximately 4 cm posterior to the umbo. A thin blocky calcitic layer (bc) (top) is seen

overlying a thicker irregular prismatic (aragonitic) layer (pa). Scale bar represents 5 µm. (C) Inner portion of the outer prismatic (pa) layer [middle prismatic layer of Blackwell *et al* (1977)] approximately 4 cm from umbo (of a specimen with a length of 8 cm). The different appearance of this layer in Figs. 1 A, B and C results from differential fracturing. Scale bar represents 5 µm. (D) Inner shell layer in the region of an irregular prismatic (pa) + homogeneous (h) sub-layer. Nacreous tablets grade into fine-grained structures at the top of the micrograph and the prisms grade into nacre (n) at the bottom. The specimen was sampled from Gulf of Maine waters. Scale bar represents 10 µm.

well as calcite-aragonite differentiation methods outlined by Schneidermann and Sandberg (1971).

RESULTS AND DISCUSSION

From the periostracum inwards, calcified structural layers of the mature *G. demissa* shell consist of: (1) blocky calcite (Fig. 1A, B); (2) prismatic aragonite (Fig. 1A-C); (3) nacre (Fig. 1A, C); (4) prismatic aragonite (pallial myostracum); and (5) alternating sub-layers of aragonitic prisms (and, occasionally, homogeneous structures) and nacre (Fig. 1D). This description differs markedly from that presented by Blackwell *et al* (1977). Discrepancies between our own observations and those of Blackwell *et al* (1977) result primarily from the fact that the latter workers only examined sections from portions of the shell outside the pallial line (L.F. Gainey, Jr. and M.J. Greenberg, personal communication). As a result, neither the relatively prominent pallial myostracum, nor the extensive inner shell layer, with its alternating sub-layers, were observed. A further discrepancy arises regarding the structure of the outermost shell layer. Blackwell *et al* (1977) describe the structure of this calcitic layer as prismatic, while reporting that the ultrastructure of this layer "could not be observed in stained, polished sections examined with the SEM." In recent shell structure literature (Kennedy *et al*, 1969; Taylor *et al*, 1970) the term "prismatic" has a relatively specific connotation. No evidence is presented by Blackwell *et al* (1977) to warrant the employment of this term to describe the structure of the outermost shell layer. The ultrastructural appearance of this layer, as seen in Figure 1 B, renders the term "blocky calcite" far more appropriate than "prismatic."

The thickness of the shell layers outside of

and including the pallial myostracum gradually increases from the umbonal region to the posterior margin. As a result of this observation, the relatively constant shell layer thicknesses reported by Blackwell *et al* (1977) are considered misleading, if not inaccurate.

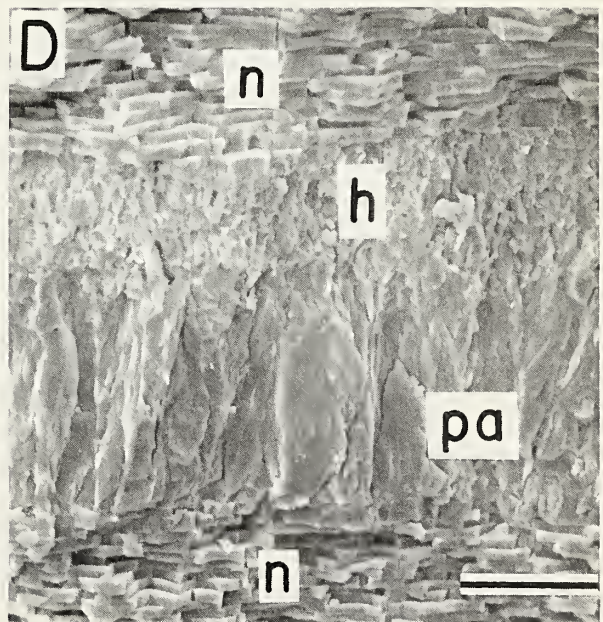
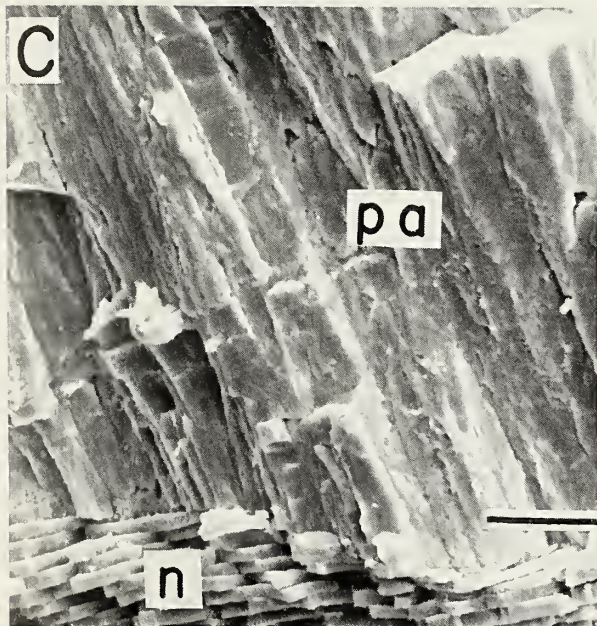
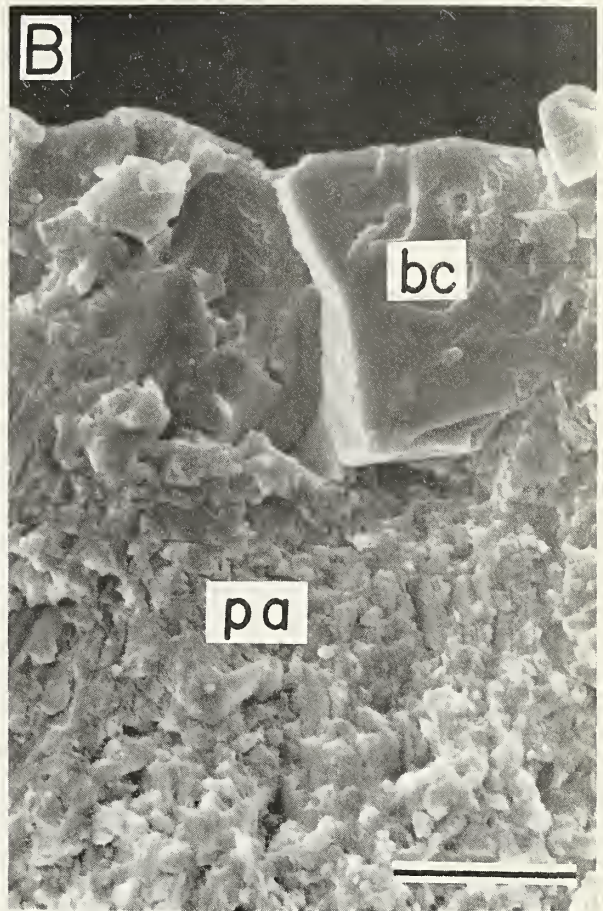
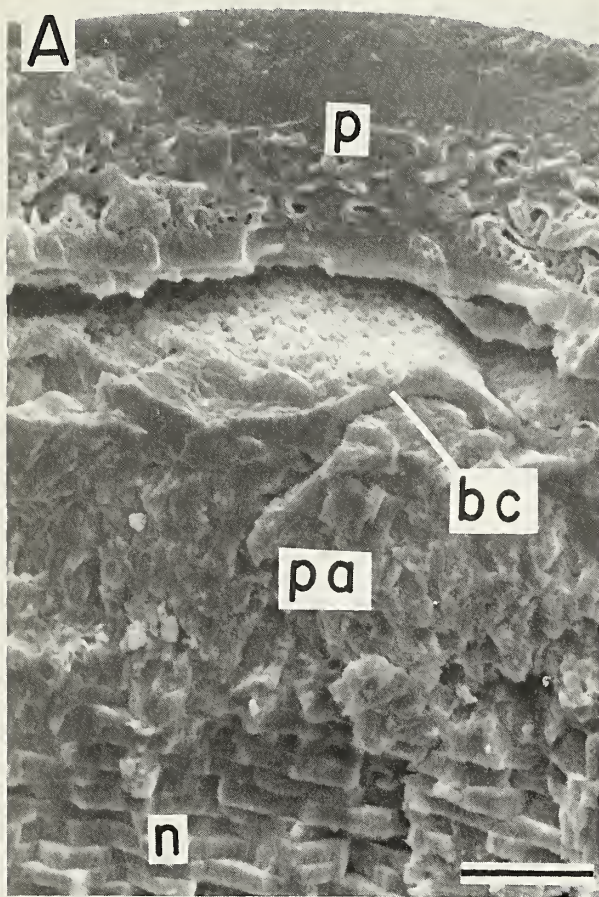
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Anodonta grandis forma *grandis* Say, 1829. Specimens occurred at all collecting sites but were abundant in the upper portions of the lake.

Anodonta grandis forma *stewartiana* Lea, 1834. Valentine and Stansbery (1971) placed *stewartiana* as a form of *A. grandis*. This may be correct, but I observed no integrades of the form *grandis* with the form *stewartiana* in this lake. Murray (1972) reported the same situation in Lake LBJ, Texas and indicated that the presence of these two forms in the same localities of a lake with no integrades required further consideration of this taxonomic relationship. Both forms *grandis* and *stewartiana* are common in Lake Corpus Christi.

Anodonta imbecilis Say, 1829. *A. imbecilis* was common at sites I and IV and rare at sites II and III.

Cyrtonaias tampicoensis (Lea, 1838). This is *Lampsilis tampicoensis* Lea as listed by Strecker (1931). In Texas, this species is highly variable in



curing at higher temperatures (Lange *et al.*, 1972). Similarly, Wilbur (1972) has suggested that during periods of "adverse environmental conditions," shell decalcification may predominate over growth. The gradation in fractured, as well as polished and etched, vertical shell sections of *G. demissa* nacreous laminae into fine-grained structures (suggestive of massive erosion) instead of irregular prisms (Fig. 1 D) tends to support this view. As water temperatures rise during the spring, the sequence of events described above is reversed.

Examination of shell growth surfaces and fracture sections of specimens from six populations from Prince Edward Island to Cape Cod, Massachusetts, revealed seasonal variation in the structure of the inner layer similar to that encountered in the specimens from the Damariscotta estuary. However, a significantly smaller proportion of homogeneous structures was observed in specimens obtained from the more southern localities. In specimens sampled from populations south of Cape Cod, seasonal variation in the structure of the inner shell layer is somewhat more complex. While alternating sub-layers (associated with cold-water shell deposition and dissolution) similar to those observed in more northern populations are still encountered, additional irregular prismatic sub-layers, associated with shell processes occurring during extremely warm summer temperatures, are also found. Such structural changes may be associated with the increased utilization of anaerobic pathways during the hot summer months when oxygen solubility is markedly reduced. In none of the specimens encountered, however, have homogeneous structures been observed in such "warm-water" sub-layers. This may well indicate decreased shell destructive processes at extremely high (relative to extremely low) temperatures. When viewed in longitudinal section, such complex seasonal variation often results in an alternation of three distinct sub-layers within the inner layer: (1) irregular prismatic + homogeneous ("cold-water" sub-layer); and (3) nacre. These three types of sub-layers are generally present in the majority of specimens sampled from populations between Cape Cod and Cape Hatteras. In more southern populations, homogeneous structures are absent, resulting in an alternation of only irregular prisms and nacre. or only irregular prisms and nacre.

The results of the present study suggest that careful examination of structural changes within the shells of certain bivalves may be of considerable assistance in reconstructing paleolatitudes.

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NEW TECHNIQUES FOR PREPARING SHELLS OF BIVALVE LARVAE FOR EXAMINATION WITH THE SCANNING ELECTRON MICROSCOPE

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The external structure of bivalve larval shells, including general shape, sculpture, and growth lines may be easily examined in specimens which have been fixed without narcotization so that the valves are closed tightly and are not obscured by the velum. The study of the internal structure of the valves, the hinge, ligament, muscle scars (if visible), geometry of the valve edge, and periostracum is possible only when the larval tissue has been removed. A variety of procedures has been used to clean larval shells including: 1) the removal of preserved or relaxed soft parts from the shells with fine needles, 2) treatment with detergent and sonication, and 3) feeding live larvae to small anemones and retrieving the egested valves (Culliney, Boyle, and Turner, 1975; Turner and Boyle, 1975). We have found that all these methods are tedious, result in a tremendous wastage of larvae, and yield preparations in which the valves are disarticulated and are not completely clean. Switzer-Dunlap and Hadfield (1977) cleaned opisthobranch larvae by boiling the larvae in 70-80% Chlorox or by feeding them to anemones.

Our work on the biology of teredinid (Bivalvia; Teredinidae) larvae requires a simple, reliable method for cleaning larval shells. The procedures we use may be divided into two parts: 1) removal of the soft parts and cleaning the larval shells, and 2) the preparation of the cleaned shells for examination with the scanning electron microscope (SEM).

REMOVAL OF SOFT PARTS AND CLEANING OF LARVAL SHELLS

For best results the larvae must be living and the outer surface of their valves free of fouling by bacteria or other microorganisms. Fixed larvae can be handled as indicated above, but the results are usually unsatisfactory. Brooded larvae present no problem as they are protected within the parent and, if carefully removed from the brood pouch or picked up immediately as they are spawned, the outer surfaces of their valves are clean. Larvae of oviparous species and short-term brooders must be raised in culture until they reach the desired stage of development. Consequently they are susceptible to fouling but by rearing cultures or holding larvae obtained from the plankton in 1 μ m filtered seawater the problem is greatly reduced. Fouling such as that shown in Plate 1 cannot be removed and even if the fouling consists only of bacteria its removal often injures the shells. The methods we use in rearing larvae are essentially those outlined by Culliney, Boyle and Turner (1975) except that we usually filter the water with a .2 μ m filter (Gelman Acroflow II cartridges) if the specimens are being reared especially for SEM studies. Starting with clean, healthy larvae will save many hours of work and prevent problems later in the process of SEM preparation.

Marine species. Removal of the soft parts from the

shells of marine larvae is based on osmotic disruption. Larvae from a culture or the brood pouch of a gravid female are pipetted onto a nitex sieve of a mesh size small enough to retain them. They are washed thoroughly with distilled water and are then placed in a 2 dram snap cap vial (Wheaton No. 24824) with about 9 ml of distilled water. These vials seal tightly and have a wide mouth so that the contents may be observed with a dissecting microscope thus minimizing the shifting of larvae from one container to another.

When first placed in distilled water the larvae close their valves tightly. After a minute or two the valves slowly open and the velum and foot, if the larva is a pediveliger, are protruded and then swell. Within one-half to one hour the larval tissue is largely disintegrated. The vial is then capped and shaken vigorously to wash the tissue out of the shells. The liquid is then removed from the vial with a transfer pipet, fresh distilled water is added, and the entire process repeated until the liquid is clear, i.e., no tissue debris remains. At this point equidimensional-umbo to pediveliger stage larvae are usually clean. This can be checked with a dissecting or compound microscope. The tissue is not as easily washed from smaller larvae, perhaps due to the slight gape of their valves. It is usually necessary in such cases to add a small amount of sodium hydroxide (1 - 3 drops of 1N NaOH per 9 ml of distilled water) to the vial. Storage overnight in this solution generally cleans the remaining tissue from the valves. Thoroughly cleaned shells can be stored in distilled water for several days before proceeding further, thus allowing several different developmental stages or species to be processed simultaneously. When this is done the pH of the distilled water should be raised to approximately 10 with sodium hydroxide to prevent the dissolution of the shells. Prior to dehydration the sodium hydroxide must be removed from the sample with three 10 minute washes with distilled water. The specimens are then dehydrated in a graded series of acetones (5 minutes in each of the following: 10%, 30%, 50%, 70%, 90%, and 4 washes in 100% acetone). 100% acetone is a convenient stopping point. We routinely store specimens in 100% acetone for periods ranging from one day to two weeks and specimens stored for ten months showed no signs of deterioration when examined with a compound microscope.

Results obtained by applying these procedures to pediveligers of *Teredo navalis* L. are illustrated on

Plate 2, figures 1, 2, 3, and 5. The larval tissue has been completely removed even from the deeply recessed umbo (U), yet the shells remain intact and articulated (fig. 1). Careful culturing techniques result in a clean outer surface of the shells (fig. 2) with both prodissoconchs 1 (P₁) and 2 (P₂) clearly visible (fig. 2). Prodissoconch 1, the shell secreted by the shell gland, has a maleated surface in all teredinid larvae we have examined. Prodissoconch 2, the larval shell secreted by the mantle edge, has characteristic growth lines. These lines or rings record the growth of the shell, outlining the dimensions of the shell at all developmental stages. The straight hinge (length > height), equidimensional umbo (length = height) and post-equidimensional umbo (length < height) stages in larval growth are easily discerned. Likewise the length of the hinge line of the straight hinge stage can be accurately measured on SEM prints. For example in figure 2, the hinge measures 50 μ m as compared with an average of 51.3 μ m for larvae at time of spawning, as given by Culliney (1975) in his study of *Teredo navalis*. Because the valves remain articulated (figs. 1, 5) it is possible to see the interdigitation of the hinge teeth and the relation of the valve edges. The edges of the lower valve in figure 1 form a thin lip which fits into a groove on the inner edge of the upper valve (figs. 3, 5). When the valves are broken apart (fig. 3) a more detailed examination of the hinge is possible. We are confident that our preparatory techniques do not destroy the periostracum because 1) the outer surface of the valves is covered by a smooth sheet which extends a short distance inward around the inner lip of the shell (fig. 4), and 2) the valves are held together at the hinge line by an external "larval ligament" (L), a thickening of this continuous sheet of periostracum (fig. 3). It is undoubtedly responsible for maintaining the gape seen in all larval shells examined to date.

Frozen larvae. Larvae may be frozen at any stage in their development and later thawed and cleaned. While this initially appears convenient, we have found that frozen larvae, like fixed larvae, are difficult to clean and produce preparations inferior to those obtained from living larvae.

The larvae figured on Plate 2, figures 4 and 6 were from a frozen adult oyster, *Ostrea edulis* L. which was thawed in warm tap water. The larvae were removed from the gill, pipetted into distilled water and shaken. The distilled water was changed 10 times over a period of 2½ hours. While this proce-

dure removed small pieces of the adult tissue which had been intermixed with the larvae, it did not remove all the larval tissue. Therefore sodium hydroxide (3 drops of 1 N NaOH per 9 ml distilled water) was added to the vial containing the larvae. Following storage in this solution overnight (12 hours) the larvae appeared clean. They were washed in distilled water and dehydrated in acetone. Only a rather small portion of the larvae survived the cleaning process intact and the results, as seen in figs. 4 and 6, are inferior to those obtained using living larvae. While unbroken larvae are, in gross structure, almost identical to larvae prepared from live specimens they are dirty (compare figs. 1 and 3 with 4 and 6). Consequently a considerable amount of SEM time is wasted searching for entire, intact larvae clean enough to photograph.

Freshwater clams. It is not possible to clean larvae of freshwater species by osmotic disruption with distilled water. Treatment with a weak base appears to be the most effective method for removing larval tissue in freshwater species.

Specimens of *Anodonta cataracta* Say and *Lampsilis radiata* (Gmelin) were collected in Halfway Pond, Plymouth Co., Massachusetts and held in an aquarium in the laboratory. After removal of one valve a small part of the marsupium was teased apart and the glochidia (larvae) were removed with a transfer pipet and placed in a vial of distilled water. Following removal of pieces of conglutinate and gill by alternate shaking and decanting of the distilled water, sodium hydroxide (2 drops of 1N NaOH per 9 ml distilled water) was added to the vial. The larvae, which up to this point had rested on the bottom of the vial with their valves gaping, snapped shut. Within 30 seconds they began to pop open, gaping as they had both within and after removal from the marsupium (gill pouch). The larval tissue disintegrated rapidly and within 10 minutes the valves were clean (as determined by observations with a dissecting microscope). The valves were then washed twice by shaking in distilled water and were stored overnight (12 hours) in distilled water made slightly basic with sodium hydroxide to prevent dissolution of the valves. The valves were then washed twice in distilled water and dehydrated in acetone.

The results are shown on Plate 3. The valves are perfectly clean and are articulated at approximately the same angle observed when the glochidia were still within the marsupium. The hooked larvae of *Anodonta cataracta* and the hookless larvae of

Lampsilis radiata represent the two principle types of glochidia present in the Unionidae (LeFevre and Curtis, 1910; Heard and Gluckert, 1970). Aside from superficial differences: shape and size, and the presence or absence of hooks, the basic structure of these larval shells appears to be identical. The outside of the valves is covered by a thin sheet of material (periostracum) which joins the two valves together mid-dorsally along the whole length of the hinge. It is reflected inward and is thickened at the middle of the hinge to form an internal "larval ligament" (L), as shown in figures 5 and 6. The outer covering also extends inward around the lip of the shell and appears to cover the hook of the glochidium of *Anodonta cataracta* (figs. 3, 7, 8). The inner calcareous portion of the valve is penetrated by many pores which extend perpendicularly through it but do not penetrate the periostracum (figs. 5, 6). Though the outer surfaces of the valves (figs. 1, 2, 7, 9) appear to be covered with pores, this is an artifact of the scanning electron microscopy. At the acceler-



Plate 1. Scanning electron micrograph of a critical point dried pediveliger of *Bankia gouldi* (Bartsch) heavily fouled with vorticellid protozoans and diatoms. Bar = 100 μ m, 292 x.

Plate 2

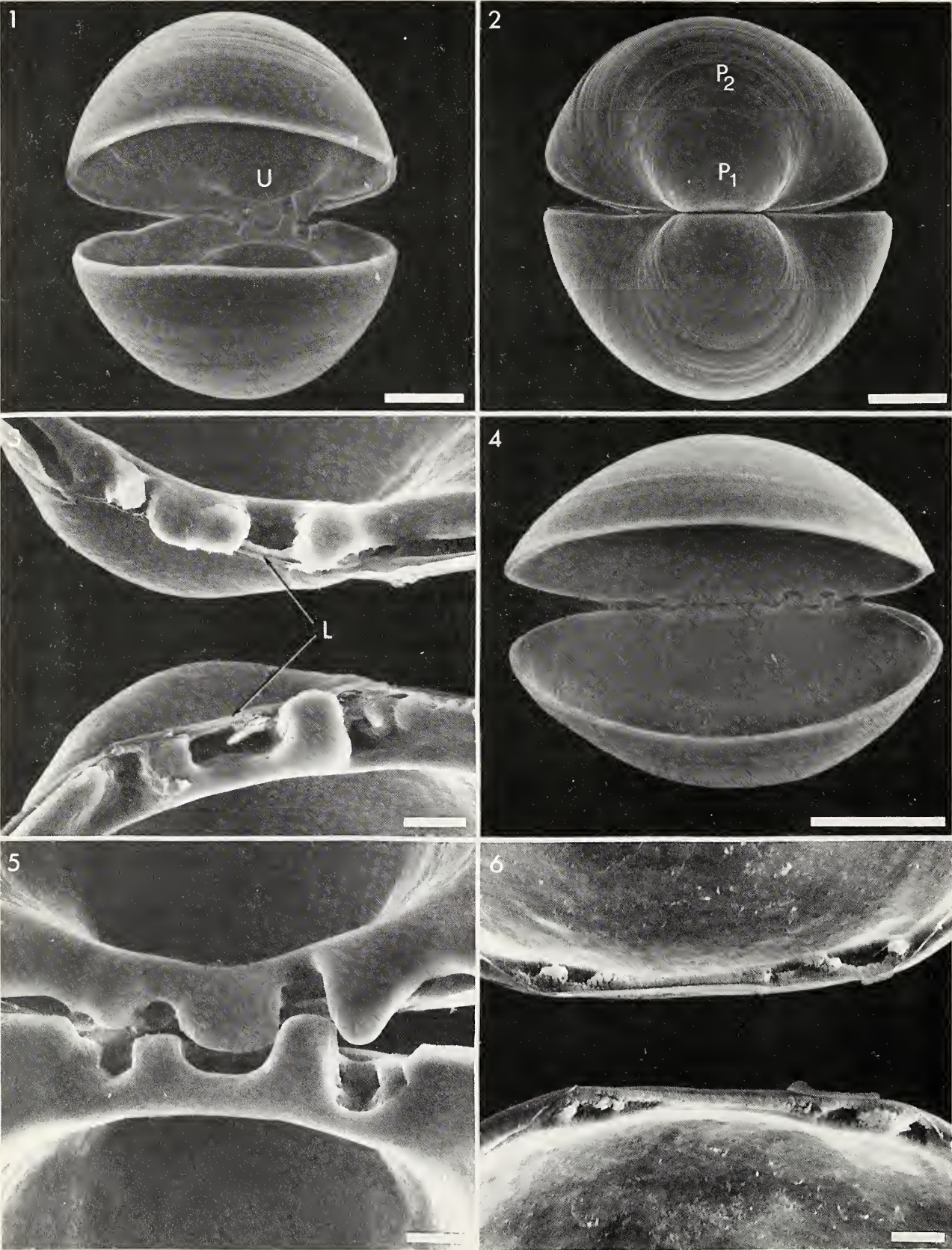


Plate 3

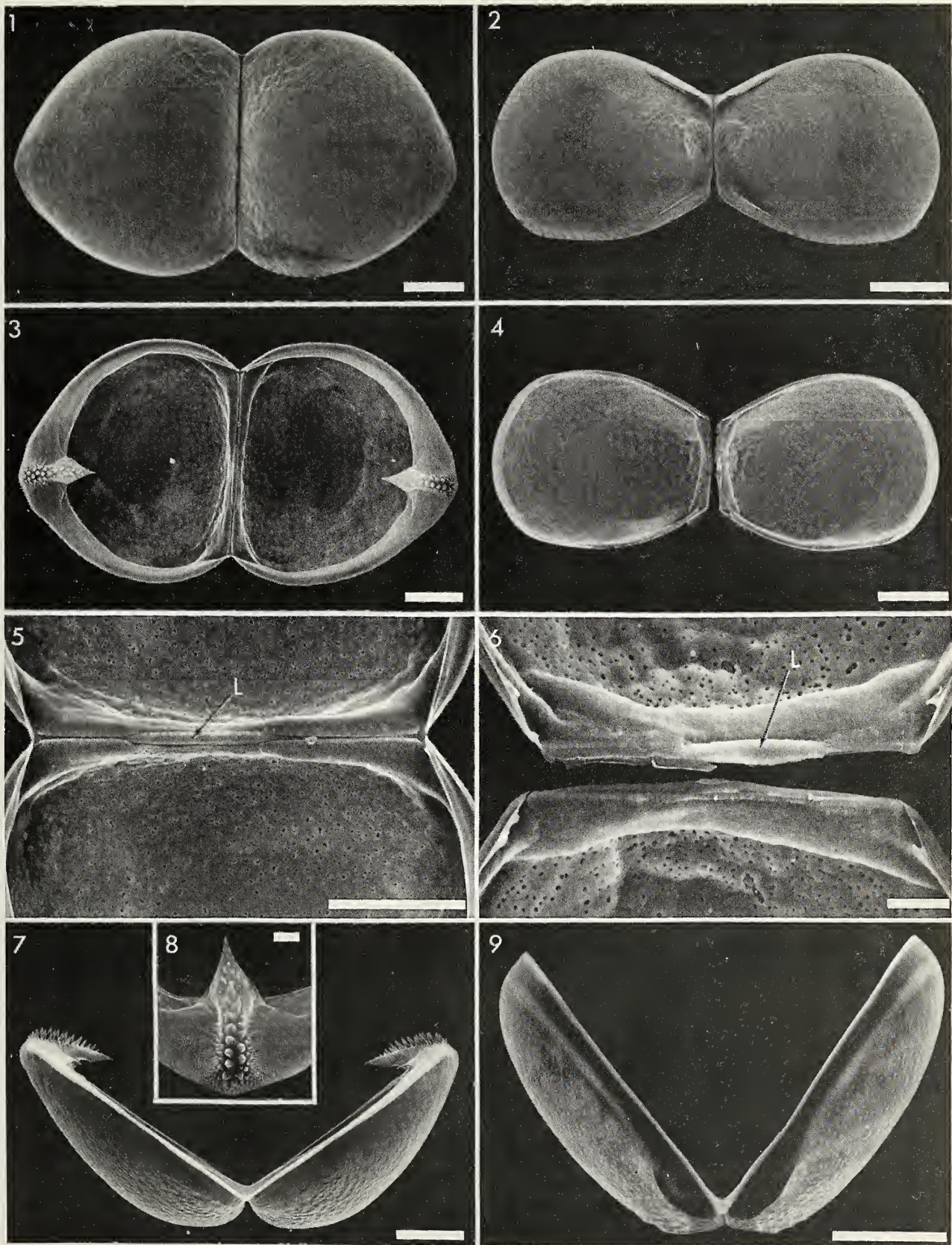


Plate 2 Scanning electron micrographs of *Teredo nautilus* and *Ostrea edulis* larvae.

Figures 1-3, 5. *Teredo nautilus* Linnaeus, Woods Hole, Massachusetts.

Fig. 1. Ventral view of gaping valves (slightly more than normal) looking dorsally at the hinge articulation, the deep umbral cavities (U) and the "tongue and groove" fitting of the valves. Bar = 50 μ m, 270 x.

Fig. 2. Umbonal view of articulated valves showing prodissococonchs 1 (P₁) and 2 (P₂). Bar = 50 μ m, 270 x.

Fig. 3. Conventional view of hinge showing the external "larval ligament" (L) which was broken when the valves were separated. Bar = 10 μ m, 936 x.

Fig. 5. Enlargement of hinge area of specimen in Fig. 1 showing the nearly perfect fit of the opposing teeth and sockets. Bar = 10 μ m, 987 x.

Figures 4 and 6. *Ostrea edulis* Linnaeus obtained from the Environmental Systems Laboratory, Woods Hole, Massachusetts.

Fig. 4. Ventral view of gaping valves (approximately normal) looking dorsally at the hinge articulation. Bar = 50 μ m, 461 x.

Fig. 6. Enlargement of the hinge area of separated valves showing the two widely separated groups of small teeth. Bar = 10 μ m, 937 x.

Plate 3 Scanning electron micrographs of the glochidia of *Anodonta cataraeta* Say and *Lampsilis radiata* (Gmelin) from Halfway Pond, Plymouth County, Massachusetts.

Figures 1, 3, 5, 7 and 8. *Anodonta cataraeta*.

Fig. 1. External surface of articulated valves showing the triangular shape, malleated sculpture and straight hinge. Bar = 100 μ m, 103 x.

Fig. 3. Internal surface of articulated valves showing the infolding of the periostracum, the elaborately dentate ventral hooks and the straight hinge. Bar = 100 μ m, 100 x.

Fig. 5. Enlargement of hinge area of specimen in Fig. 3 showing the infolded, thickened periostracum forming the "larval ligament" (L) and the pores which penetrate the calcareous portion of the valves. Bar = 100 μ m, 231 x.

Fig. 7. Profile view of articulated valves showing the large highly dentate hooks, malleated sculpture, and normal angle of gape. Bar = 100 μ m, 117 x.

Fig. 8. Enlargement of right hook in Fig. 3 showing detail of dentition. Bar = 20 μ m, 222 x.

Figures 2, 4, 6 and 9. *Lampsilis radiata*.

Fig. 2. External surface of articulated valves showing rounded ventral margins, straight hinge, and malleated sculpture. Bar = 100 μ m, 137 x.

Fig. 4. Internal surface of articulated valves showing smooth ventral margins lacking hooks. Bar = 100 μ m, 122 x.

Fig. 6. Enlargement of hinge of specimen in Fig. 4 showing "larval ligament" (L) and pores which penetrate the calcareous portion of the valves. Bar = 20 μ m, 541 x.

Fig. 9. Profile view of articulated valves showing smooth ventral margin and malleated sculpture. Bar = 100 μ m, 193 x.

ating voltage used (20 KV) the electrons penetrate the thin periostracal covering causing it to become transparent and thus revealing the underlying pores. This artifact can be removed by using a lower accelerating voltage. As the outside surface of the valves has an uneven texture much like that of prodissoconch 1 (P₁) of teredinids and as growth lines are absent, it appears possible that the entire glochidial shell is produced by a shell gland.

All the procedures outlined above for the unionids can be easily carried out in the field as they require only living gravid females, a minimum of dissecting equipment, pipets, distilled water, 2 dram vials, NaOH, acetone, a graduated cylinder and the tail board of a station wagon. Working with fresh, clean larvae in the field greatly reduces the time required to clean the shells and insures prime preparations.

PREPARATION OF CLEANED SHELLS FOR EXAMINATION WITH THE SEM

Prior to examination with the SEM, specimens must be: 1) dried, 2) mounted on specimen stubs, and 3) coated.

Drying. Larval shells are hard specimens and would probably not be adversely affected by air drying from water or from a fluid of low surface tension such as acetone or ethanol. Our research not only involves larval shells but also whole fixed larvae which must be critical point dried. Therefore all of our larval material to be examined with the SEM is critical point dried using carbon dioxide as a transitional fluid. The technique of critical point drying biological specimens was introduced by Anderson (1951) and is perhaps the most widely accepted method for drying soft biological specimens for examination with the SEM (for a review of these techniques see Cohen, 1974).

Containers or carriers for small specimens which are to be critical point dried are not provided by the manufactures of most critical point dryers. Convenient specimen carriers can be constructed from Beem capsules as described by Cohen and Garner (1971). The end of the Beem capsule is cut off to form a cylinder and the centers of two caps are cut out to form retaining rings to secure the nylon screens. Nitex monofilament nylon screens having a mesh opening of 37 μ m (Tetko Inc., 420 Saw Mill River Road, Elmsford, NY, 10523, Cat. No. HC-3-37) will retain all but the smallest larvae. Once specimens have been critical point dried they should be stored in a dessicator to protect against moisture and

dust. We have successfully stored specimens in their carriers in a dessicator for 8 months prior to mounting.

Mounting. Whole critical point dried larvae are mounted on Scotch double-stick tape following the procedure outlined by Turner and Boyle (1975). This procedure allows larvae to be mounted individually and with the desired orientation. If the background, double-stick Scotch tape, is perfectly flat and homogenous and is positioned perpendicular to the Z axis (beam axis) of the microscope (tilt = $0^\circ \pm 10^\circ$) then photographs will have a solid black background. Therefore, in order to obtain a black background, the specimens must be oriented on the stub so that the surface to be photographed is parallel to the surface of the stub. That is, the specimen should have the same orientation in the SEM as it does when the stub is observed with a dissecting microscope. Scanning electron micrographs with a black background have several advantages: 1) the image stands out sharply from the background, 2) it is not necessary to rout the image from a distracting background and remount it, 3) small bits of dirt which fall on the background and appear as white spots may easily be removed photographically. Careful mounting of the specimens not only improves the results but also decreases the amount of SEM time required to examine the specimens.

Coating. Prior to examination the specimens are coated with carbon followed by gold-palladium in a sputter coater. If a sputter coater, rather than a vacuum evaporator, is used for coating one must be careful not to expose the specimens to excessive heating during the deposition of the gold-palladium. Heating the specimen not only contributes to its deterioration but also causes the tape to wrinkle, thus producing a very disruptive background. Several light coats of gold-palladium with a complete venting of the sputter coater between coats will help eliminate the heating problem. The specimens should be coated immediately prior to examination as the tape, once coated, at least in our sputter-coater, will begin to wrinkle within about one day.

Careful printing of the negatives is also essential to the production of fine photographs, the end product of all the work and techniques outlined here. From beginning to end, patience, cleanliness and a good SEM operator are essential to success in the science and art of Scanning Electron Microscopy.

ACKNOWLEDGEMENTS

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DISCOVERY OF TWO DISTINCT KINDS OF STATOCYSTS IN FRESHWATER BIVALVED MOLLUSKS: SOME BEHAVIORAL IMPLICATIONS

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Statocysts are organs generally understood to be associated with equilibrium/balance and are widely distributed through the animal kingdom. Attached by a nerve to a central nervous apparatus in an animal, a statocyst is commonly a small sphere embedded in connective tissue. The sphere is lined with sensory epithelial cells and encloses a fluid-filled cavity in which tiny statoliths may float. Movement of the animal results in movement of the statoliths, in turn stimulating the lining cells. Sensory information may then be transmitted along the attached nerve to the central nervous system.

In bivalved mollusks statocysts are located deep

within the tissues of the foot. Published information on details of their structure is limited (Bayne, Widows and Thompson, 1976; Barber, 1968; Bullock and Horridge, 1965). Experimental evidence for their function is scanty. Buddenbrock (1913) experimentally implicated the statocysts of *Chlamys varia* as organs of equilibrium. In this report I will note and describe striking contrast in the structure of the statocysts of two freshwater bivalves, the unionacean, *Lampsilis*, and the sphaeriacean, *Corbicula*. I will then note possible implications of these findings as they may be related to contrasting behaviors of the two kinds of animals.

MATERIAL AND METHODS

Preparation of *Lampsilis* and *Corbicula* material involved the relaxation, fixation, embedding and staining techniques described elsewhere (Kraemer, 1978). *Lampsilis* statocysts were removed from mature, relaxed, fixed specimens by dissection. This was done by locating a cerebral ganglion (within muscular tissue postero-lateral to the mouth) and following the cerebro-pedal connective to the statocyst nerve which branches posteriorly at about a 45° angle. Now following the statocyst nerve through the muscle and connective tissue into the dorsal part of the foot, one comes to a small, distinct, translucent sphere, the statocyst (Fig. 1). The statocyst may then be freed from surrounding tissues, removed from the animal and embedded, sectioned and stained. In large mussels (15 cm long) each statocyst is only about 2mm in diameter.

Corbicula statocysts were studied *in situ* in stained serial sections of the whole animal. Sagittal serial sections showed individual statocysts. However, it was only through study of serial cross-sections of a

number of these animals that the peculiar character of their statocysts was finally observed.

RESULTS

The Statocysts of Lampsilis: Each of the two statocysts of *Lampsilis* is attached to its own statocyst nerve, and is thus connected to its own cerebral ganglion. The two statocysts are deployed laterally and are consequently widely separated from each other in the animal's foot. Sections of a single *Lampsilis* statocyst show the organ to be enclosed within a connective tissue capsule. Ciliated columnar epithelial cells surround the lumen of the organ (Figs. 2, 3).

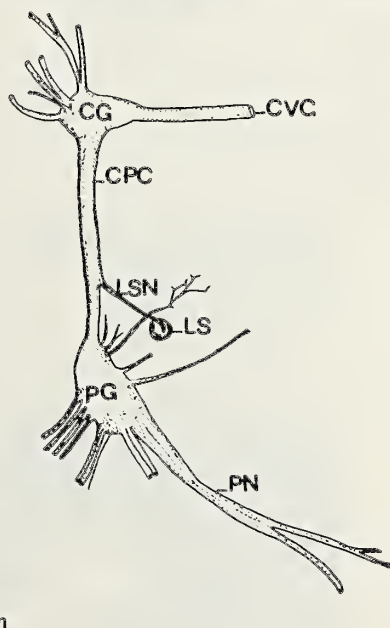


Figure 1. Dissection of anterior central nervous system of *Lampsilis ventricosa* (Barnes), showing location of the left statocyst, CG, left cerebral ganglion; CPC, left cerebropedal connective; CVC, left cerebro-visceral connective; LS, left statocyst; LSN, left statocyst nerve; PG, pedal ganglion; PN, pedal nerve(s).

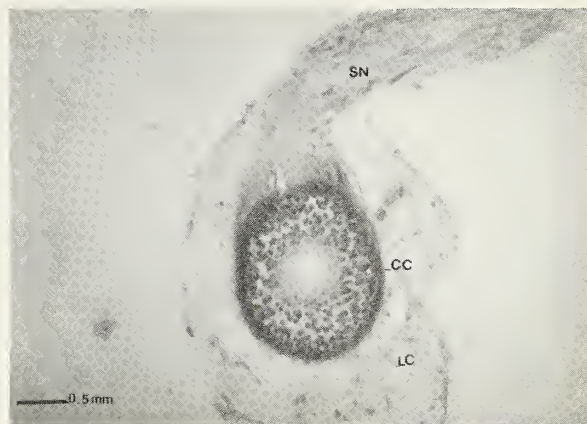


Figure 2. Left statocyst of *Lampsilis ventricosa*, showing statocyst nerve and statocyst capsule.

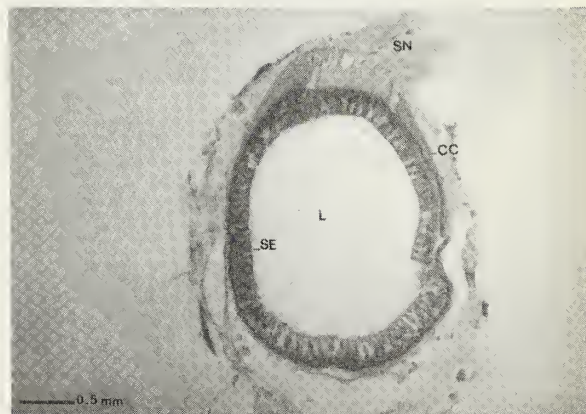


Figure 3. Left statocyst of *L. ventricosa*, showing lumen and sensory epithelial lining. CC, connective tissue capsule of statocyst; L, lumen of statocyst; LC, loose connective tissue surrounding statocyst; SE, sensory epithelium of statocyst; SN, statocyst nerve.

Statoliths occupy the organ's cavity. Composition of the statoliths was not determined in this study. The statoliths were sufficiently hardened (perhaps partly as a consequence of preparation methods) that they popped through the statocyst capsule during microtome sectioning (Fig. 4).

Innervation of the sensory epithelium of the statocyst is accomplished by penetration of the cyst capsule by the statocyst nerve. The statocyst nerve sends delicate branching fibers in among the epithelial cells (Fig. 5).

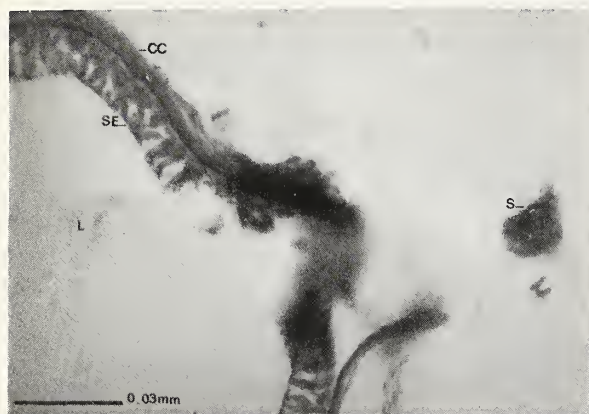


Figure 4. Section through statocyst of *L. ventricosa*, showing hardened statolith which popped through the sensory epithelium during microtome sectioning.

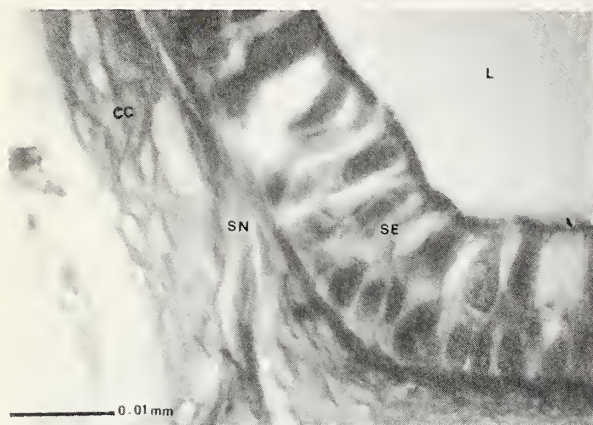


Figure 5. Section through statocyst of *L. ventricosa*, showing statocyst nerve fibers innervating sensory epithelial lining cells. CC, connective tissue capsule of statocyst; L, lumen of statocyst; S, statolith (which popped through the lining cells during section); SE, sensory epithelium of statocyst; SN, statocyst nerve fibers.

The Statocysts of Corbicula: A study of serial sections of these animals reveals the consistent presence of a pair of tiny statocysts in a patch of connective tissue immediately dorsal and adjacent to the pedal ganglion. In a 4mm long animal, each statocyst measures not much more than 100 microns in diameter. The statocysts of *Corbicula* are in the midline of the body, unlike *Lampsilis* in which the statocysts are more peripherally located. Like *Lampsilis*, however, the statocysts of *Corbicula* are positioned in the dorsal part of the foot near its

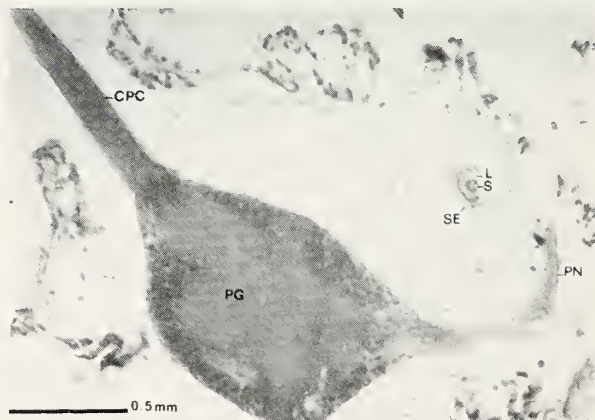


Figure 6. Sagittal section of *Corbicula fluminea* through region of pedal ganglion and statocyst. CPC, cerebro-pedal connective; L, lumen of statocyst; PG, pedal ganglion; PN, pedal nerve(s); S, statolith; SE, statocyst epithelium.

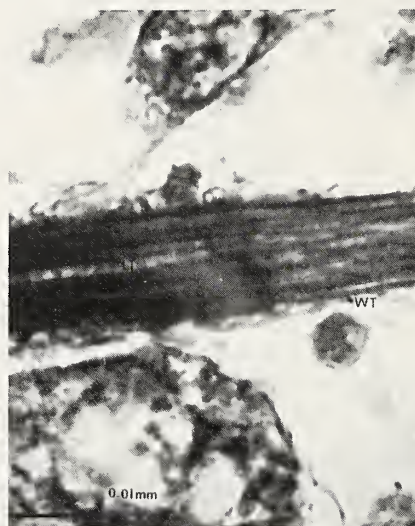


Figure 7. Transverse section through *C. fluminea* showing tube which joins left and right statocysts in the body's midline. WT, wall of statocyst tube; LT, lumen of statocyst tube.

border with the visceral mass.

Close examination shows the *Corbicula* statocysts to be comprised of unciliated, low cuboidal epithelium. There is no conspicuous connective tissue capsule. The lumen of each statocyst is nearly filled with a single statolith (Fig. 6). This study further reveals that the two *Corbicula* statocysts are *conjoined* medially by a slender, distinct tubular channel (Fig. 7). The *common statocyst tube*, as I propose to call it, is wrapped with fibers. Whether these "wrapping" fibers are derived from connective and/or nervous tissue has not yet been ascertained. Branches of small nerves from the pedal ganglion have been traced to the statocyst apparatus. No nerves from the pedal ganglion have been traced to the statocyst apparatus. No nerves from the cerebro-pedal connectives to the statocysts could be discerned. The whole *Corbicula* statocyst apparatus is shown in Fig. 8.

DISCUSSION AND CONCLUSIONS

I believe this to be the first report of a molluscan statocyst apparatus consisting of a statocyst pair and a conjoining tube. In the literature, there are references to "excretory" ducts and tubes leading to exterior pores, associated with molluscan statocysts. One finds these in recent publications (Bayne, Widows and Thompson, 1976; Barber, 1968). Figures which accompany such descriptions, however, are frequently from earlier work. For example, Bayne, et

al (1976) show a drawing made by List (1902). List's drawing shows a single statocyst with an attached tube disappearing into the animal's tissues (supposedly to the exterior) at a site labelled "pore," in the marine bivalve, *Mytilus galloprovincialis*. I suspect that some "pores" and "ducts" reportedly as-

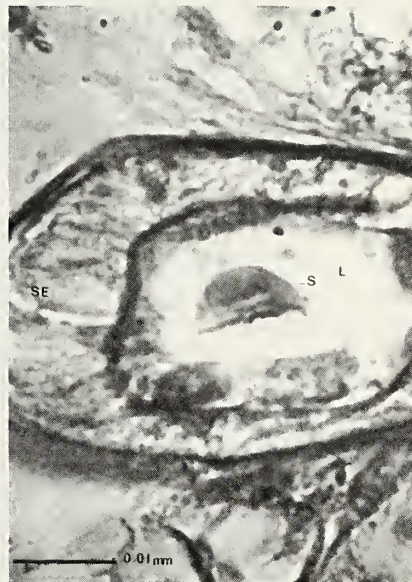


Figure 8B. Same as A, showing detail of right statocyst.

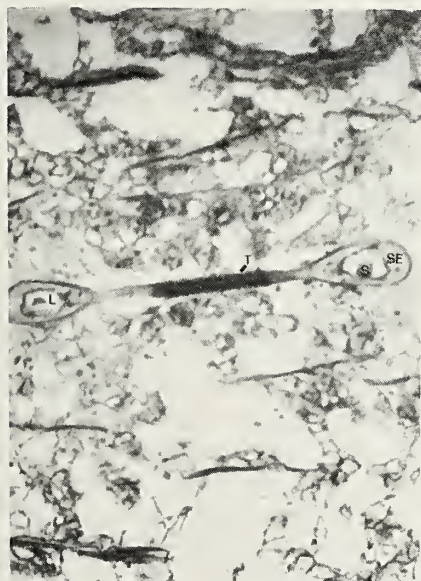


Figure 8A. Transverse section through *C. fluminea* showing conjoined statocyst apparatus in midline of body immediately dorsal to pedal ganglion.

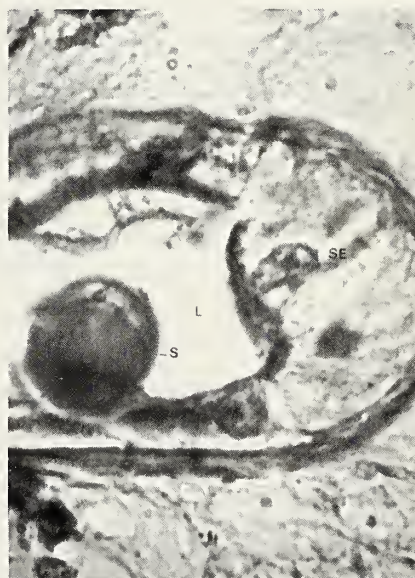


Figure 8C. Same as A, showing detail of left statocyst.

L, lumen of statocyst; S, statolith; SE, statocyst epithelium; T, conjoining statocyst tubule.

sociated with bivalves' statocysts, may possibly be part of a statocyst apparatus similar to that described here in *Corbicula*.

Some inferences may be drawn concerning the different organization of statocysts in the two kinds of freshwater bivalves, *Lampsilis* and *Corbicula*. Behavior of the *Lampsilis* foot in locomotion and in spawning activity has been described elsewhere (Kraemer, 1970). The foot's movements involve a slow "stepping" as its blood spaces fill and empty. In contrast, the foot of *Corbicula* is exceedingly mobile. Quick, delicate, back-and-forth and side-to-side movements of the whole foot remind one of a toe dancer.

Possibly, bivalved mollusks capable of active foot movements may be more likely to have a *Corbicula* type of statocyst apparatus. Those bivalved mollusks with slower foot movements might be expected to possess statocysts of the sort described here for *Lampsilis*. The *Corbicula* statocyst apparatus with its medially placed statocysts, joined by a fluid-filled tube and evidently innervated by the pedal ganglion, has the appearance of a sensory mechanism suited to rapid foot movements. It seems that any anterior-posterior, left-right deploying of the animal's foot might readily be detected by movement of fluid in the statocyst tube from one statocyst to the other.

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MARKING CLAMS AND PREDATORS OF CLAMS WITH RUBIDIUM¹

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INTRODUCTION

Many predator-prey interactions probably operate in extensive clam culture systems, and those involving the hard clam, *Mercenaria mercenaria* (Linnaeus 1758), are not fully understood. Most of the clam mortalities associated with decapod crustacean predators in these systems were attributed to the large crabs, *Callinectes sapidus* Rathbun 1896, *Carcinus maenas* (Linnaeus 1758), and *Menippe mercenaria* (Say 1818) (Menzel and Sims, 1962; Walne, 1974). Recently, Whetstone and Eversole (1978) reported *Panopeus herbstii* Milne Edwards

1834, a smaller crab, to be an important predator in an experimental clam culture system in South Carolina. Their conclusion was based on examinations of empty clam shells, estimates of the relative abundance of potential predators in the system, analysis of stomach contents of potential predators collected, and laboratory observations of predator-prey interactions. However, some difficulty was encountered in identifying the finely ground food items in the cardiac stomachs in order to reconstruct the diets of the decapod crustaceans collected. Refined techniques have been developed to help eliminate this and other problems; and one of the newer tech-

niques involves the use of non-radioactive trace elements to mark potential food items. The objective of this study was to investigate the feasibility of using non-radioactive rubidium, a form successfully used to mark terrestrial insects (Shepard and Waddill, 1976), as a marker of clams and predators of clams.

MATERIALS AND METHODS

Three initial experiments were conducted to determine: at what levels clams could safely be exposed to rubidium chloride (RbCl) and still have detectable levels of rubidium (Rb) in the tissue; how long detectable levels of Rb remained in clam tissue; and whether diatoms could be successfully labelled with Rb. Total of 36 clams (shell length, SL = 13.72 mm) in 750-ml glass aquaria were exposed to one of four concentrations of RbCl (10, 1, 0.1 and 0.01 g/l) or a control. Test concentrations and controls were prepared by serially diluting a stock solution of RbCl or NaCl in a test medium of aerated artificial seawater (32.5 g/l). Clams were exposed for 48 and 96 hours. After each exposure period one-half of the clams from each treatment were sacrificed (i.e., four clams/test concentration) and the remaining clams were transferred to untreated artificial seawater for seven days before being sacrificed. Clams were held at 20°C and a daily 14 L/10D cycle during all tests. Clams were observed every 12 hours during the experiment, and an index of biological activity (i.e., siphon extension) and rates of survival recorded. Tissues from sacrificed clams were weighed, ashed (550°C), and dissolved in 10 ml of 2N HCl. Rubidium levels were determined with an atomic absorption spectrophotometer operated in the flame emission mode of 780.02 nm line for Rb (Berry *et al.*, 1972).

On the basis of the first study, the level of RbCl for testing the retention of Rb in tissue was set at 1.0 g/l. Twelve replicates, eight experimental and four control, of 20 clams each (SL = 22.87 mm) were exposed for 96 hours and were sacrificed at 0, 7 and 30 days after exposure. Labelling the diatom *Phaeodactylus tricornutum* Bohlin 1897, a potential food for clams, was attempted as a method of improving Rb retention time by clams. Stock cultures of diatoms were held in an aerated mixture of 50% artificial seawater and 50% sterilized seawater from Charleston Harbor, South Carolina. Cultures were continuously illuminated with fluorescent and incandescent bulbs and held at 20°C. RbCl (10, 1 and 0.1 g/l) was added to experimental cultures and 1.0 g/l NaCl to control cultures. Triplicate 100-ml sam-

ples were taken at 24, 48 and 96 hours from each treatment. Samples were filtered with metricel GA-1 paper (5 µm pore size), dried and weighed before analysis.

Preliminary results helped establish levels of RbCl and techniques for testing its effectiveness in marking clams for predation studies. In one experiment, a minimum of 120 clams (SL = 22.87 mm) were reared in each of five treatments. Clams in two control treatments were held in artificial seawater without diatoms, and in artificial seawater with unlabelled diatoms. Clams in two experimental treatments were exposed to 1.0 g/l RbCl with and without labelled diatoms. In the fifth treatment clams were exposed only to labelled diatoms in artificial seawater. Diatoms were cultured for 48 hours prior to starting the experiment in media with 1.0 g/l RbCl or NaCl (unlabelled diatoms). At the start of the experiment and every 24 hours during the 96-hour exposure period, 500-ml samples of culture media and diatoms were collected and centrifuged at 2,000 rpm for 10 minutes. Supernatants were poured off, and the remaining pellet rediluted with unlabelled culture media. This process of washing the diatoms through centrifugation and redilution was repeated three times before the diatom pellet was added to the appropriate treatment. Triplicate 100-ml samples of diatoms were taken from experimental and control culturing flasks at the same time to assess the levels of Rb in diatoms fed to clams. Culture media with 1.0 g/l RbCl or NaCl removed during sampling were replaced. Clams reared in the treatments with diatoms received the amount of diatoms found in 500 ml of culture media four times (0, 24, 48 and 72 hours) during the 96-hour exposure period. Clams were sacrificed at 96 hours or were transferred to untreated artificial seawater for 7, 14 and 21 days before being sacrificed.

Two clams exposed to 1.0 g/l RbCl or NaCl were added daily for four days to each of 16 *P. herbstii* held individually in aquaria. Eight crabs, four of which ate labelled clams and four of which ate control clams, were sacrificed. The remaining crabs were each offered two control clams daily for seven days and then sacrificed. Partially consumed clams, shell bits, and fecal strands of the crabs were removed each day. Fecal strands were separated and stored frozen until analysis. Samples of hepatopancreas, gonad, cheliped muscle, and the cardiac stomach were analyzed from the sacrificed crabs.

TABLE 1.

Levels of Rb detected in clams exposed to several concentrations of RbCl for 48 and 96 hours at 0 and 7 days post-exposure. Rb concentrations expressed as content (ppm/animal) and as the weight-specific concentration (ppm/tissue dry weight-mg).

RbCl concentration (g/l)	N	ppm/animal ¹ Mean $\pm$ S.D.	ppm/tissue dwt (mg) ¹ Mean $\pm$ S.D.
Control (0)	4	0.28 $\pm$ 0.06	0.02 $\pm$ 0.01
10	3	77.62 $\pm$ 105.32	4.17 $\pm$ 3.47
1	8	25.34 $\pm$ 35.31	1.60 $\pm$ 2.05
0.1	8	4.81 $\pm$ 5.04	0.29 $\pm$ 0.24
0.01	8	1.11 $\pm$ 0.57	0.20 $\pm$ 0.38

¹Exposure and post-treatment times were combined.

TABLE 3.

Levels of Rb detected in clams after 96 hours exposure to 1.0 g/l RbCl then transferred to untreated seawater. Rb concentrations expressed as content (ppm/animal) and as the weight-specific concentration (ppm/tissue dry weight-mg).

Days post-exposure	N	ppm/animal ¹ Mean $\pm$ S.D.	ppm/tissue dwt (mg) ¹ Mean $\pm$ S.D.
0	20	109.64 $\pm$ 149.35	1.51 $\pm$ 1.86
7	20	16.18 $\pm$ 6.88	0.25 $\pm$ 0.08
30	20	3.50 $\pm$ 0.52	0.05 $\pm$ 0.01
Control ¹	20	3.21 $\pm$ 1.03	0.05 $\pm$ 0.02

¹Clams not exposed to RbCl.

TABLE 2.

Levels of Rb detected in clams 0 and 7 days after exposure to 10, 1.0, 0.1, and 0.01 g/l RbCl concentrations for 48 and 96 hours. Rb concentrations expressed as content (ppm/animal) and as the weight-specific concentration (ppm/diatom dry weight-mg).

Days post-exposure	N	ppm/animal ¹ Mean $\pm$ S.D.	ppm/tissue dwt (mg) ¹ Mean $\pm$ S.D.
0	15	30.02 $\pm$ 53.94	1.73 $\pm$ 2.41
7	12	2.72 $\pm$ 3.66	0.27 $\pm$ 0.34
Control ²	4	0.28 $\pm$ 0.06	0.02 $\pm$ 0.01

¹Exposure times were combined.

²Clams not exposed to RbCl.

TABLE 4.

Levels of Rb detected in diatoms exposed to several concentrations of RbCl for 24, 48 and 96 hours. Rb concentrations expressed as content (ppm/diatoms in 100 ml) and as the weight-specific concentration (ppm/diatom dry weight-mg).

RbCl concentration (g/l)	N	ppm/animal ¹ Mean $\pm$ S.D.	ppm/tissue dwt (mg) ¹ Mean $\pm$ S.D.
Control (0)	9	0.9 $\pm$ 0.1	0.04 $\pm$ 0.01
10	9	800.2 $\pm$ 368.6	35.56 $\pm$ 15.99
1.0	9	137.7 $\pm$ 64.0	5.74 $\pm$ 2.64
0.1	9	3.0 $\pm$ 1.5	0.17 $\pm$ 0.09

¹Exposure times were combined.

Analysis of variance, least-squares analysis of variance and Duncan's new multiple-range tests were used to analyze the data. Levels of Rb detected were calculated and compared using Statistical Analysis Systems (SAS) developed by Barr and Goodnight (1972).

RESULTS AND DISCUSSION

The results of the first experiment are presented in Tables 1 and 2. Detectable Rb levels generally increased with treatment concentration (Table 1), but decreased with time (Table 2). The most striking result of this experiment was the high level of Rb in experimental clams. The level of Rb per dry weight of clam tissue in experimental animals exceeded controls, with one exception, by more than three standard deviations. This clam was exposed to 0.01 g/l RbCl and sacrificed 7 days post-exposure. The amount of Rb detected in clams exposed for 48 and 96 hours was not significantly different ($P < 0.05$) and, thus, exposure times were combined for analysis (Tables 1, 2). RbCl concentrations did not exhibit any toxicity during exposure and post-exposure periods at levels less than 10 g/l. Biological activity (siphon extension) of clams in concentrations below 10 g/l RbCl was similar to the activity of clams in untreated seawater.

To test how long clam tissue retained Rb after exposure, 1.0 g/l RbCl was selected because little difference in biological activity was noticed with

clams between 1.0 g/l and lower concentrations, and clams exposed to this concentration had significantly higher ($P < 0.05$) Rb levels than clams exposed to 0.1 and 0.01 g/l RbCl, respectively (Table 1). When clams were tested at 1.0 g/l RbCl, the amount of Rb present in clam tissue declined rapidly to an average of 0.25 ppm Rb/tissue dry weight (mg) by 7 days and equalled the control level by 30 days (Table 3). A similar decline was observed over the first 7 days in the first experiment (Table 2). If the decline in the amount of Rb in clam tissue followed a smooth logarithmic decrease, significant Rb levels in tissue would be expected to be detectable up to three weeks. This hypothesis was examined in a following experiment.

As in the case of clams exposed for 48 and 96 hours to RbCl, very little difference in the amount of Rb was detected in *P. tricornutum* after the 24, 48 and 96-hour exposure periods. Because of this, exposure times of diatoms to RbCl were combined for analysis (Table 4). The Rb/dry weight of diatoms at all three exposure concentrations was significantly higher ($P < 0.05$) than controls or Rb levels that naturally occur in *P. tricornutum*. The significance of the elevated Rb content at 1.0 g/l RbCl becomes more impressive when one considers that this RbCl level in solution is relatively non-toxic to clams and an effective labelling concentration. Thus, RbCl at 1.0 g/l was used to further test the relative permanency of a Rb marker by feeding clams diatoms labelled with Rb.

TABLE 5.

Levels of Rb detected (Mean $\pm$ S.D.) in clams exposed to one of five treatments for 96 hours then transferred to untreated seawater. Rb concentration expressed as the weight-specific concentration (ppm/tissue dry weight mg).

Days		Control		Experimental		
post-exposure	N ¹	w/o Diatoms ² w/o RbCl	w/Diatoms ³ w/o RbCl	w/Diatoms ⁴ w/o RbCl	w/o Diatoms ⁵ w/RbCl	w/Diatoms ⁶ w/RbCl
0	35	0.014 $\pm$ 0.006	0.013 $\pm$ 0.002	0.027 $\pm$ 0.006	1.485 $\pm$ 0.437	1.577 $\pm$ 0.461
7	35	0.011 $\pm$ 0.002	0.013 $\pm$ 0.002	0.013 $\pm$ 0.001	0.033 $\pm$ 0.012	0.044 $\pm$ 0.014
14	32	0.016 $\pm$ 0.004	0.014 $\pm$ 0.003	0.022 $\pm$ 0.004	0.026 $\pm$ 0.006	0.020 $\pm$ 0.002
21	32	0.012 $\pm$ 0.001	0.013 $\pm$ 0.002	0.018 $\pm$ 0.002	0.022 $\pm$ 0.002	0.026 $\pm$ 0.004

¹Number of clams analyzed from each post-exposure period.

²Control culture without diatoms and RbCl.

³Control culture with unlabelled diatoms and without RbCl.

⁴Experimental culture with labelled diatoms and without RbCl.

⁵Experimental culture without diatoms and with RbCl.

⁶Experimental culture with labelled diatoms and RbCl.

Clams exposed to a 1.0 g/l solution of RbCl with and without diatoms or a control solution, NaCl only, with labelled diatoms for 96 hours contained enough Rb to be significantly higher ($P < 0.05$) than the amount of Rb detected in control clams. Inspection of the data reveals that the amount of Rb detected in clams reared in RbCl solutions was significantly higher ($P < 0.05$) than the controls, with one exception, through all post-exposure times (Table 5). The one exception was the exposure of clams to 1.0 g/l RbCl with labelled diatoms and the control without diatoms and RbCl at 14 days post-exposure. Obviously, clams labelled in 1.0 g/l solutions of RbCl can retain significant levels of Rb for at least three weeks, agreeing with an *a priori* prediction.

Access to Rb-labelled diatoms in the culture media appeared to aid Rb labelling of clams. When clams were allowed to feed on diatoms with Rb in untreated seawater, the content of Rb in clams was significantly higher ($P < 0.05$) than all controls except at 7 days post-exposure (Table 5). This low level seven days after exposure may be due to sampling error because elevated Rb levels were detected at 14 and 21 days post-exposure. Some Rb must be incorporated in clam tissue because the gut contents (labelled diatoms) of clams should have been eliminated before day 21. Rubidium may replace some of the potassium in the tissue (Evans and Sorger, 1966).

A considerable increase in the amount of Rb was detected in clam tissue in relation to the amount of

Rb available when clams were exposed solely to labelled diatoms. The Rb introduced in the culture medium was approximately 148 ppm/500 ml of medium or less than 10 ppm Rb of diatomaceous food per clam for experimental period. Assuming the clams removed all the diatoms from the water and retained all the Rb in the diatoms (a gut efficiency of 100%) the calculated average maximum Rb content per clam at 0 days post-exposure would be 0.156 ppm Rb/dry weight of clam tissue (mg). The Rb actually detected in clam tissue or as undigested diatoms in the gut immediately after exposure was 17.3% of the total amount available. The low level of Rb available to each clam in diatoms and clam gut efficiencies considerably less than 100% are two reasons why labelled diatoms did not significantly increase the retention time of Rb in clam tissue.

Detectable amounts of Rb were found in all the tissues of *P. herbstii* examined (Fig. 1). Significantly higher ($P < 0.05$) amounts of Rb were found in the hepatopancreatic tissue of experimental crabs after the first 96 hours of feeding. Muscle tissue from the cheliped of experimental crabs contained more than three times the Rb found in the muscle tissue of control crabs at 0 days (Fig. 1), but this difference was not significant ($P < 0.05$). Clams offered to experimental crabs averaged 44 ppm of Rb compared to less than 1 ppm Rb for the unlabelled clams. Not all the crabs ate the clams presented; using the number of clams consumed, the Rb consumed per crab averaged 294 ppm. Crabs did not retain all the Rb eaten; fecal strands of experimental crabs had elevated levels of Rb. The Rb content of fecal strands peaked at 132 hours or 36 hours after the feeding of labelled clams was stopped. The amount of Rb in fecal strands approached the levels of controls by 7 days, indicating most of undigested Rb-labelled clam had been eliminated. Also, no apparent difference in amount of Rb was detected in the four tissues analyzed from experimental and control crabs at 7 days.

It can be concluded from this study that *Phaeodactylus tricornutum*, *Mercenaria mercenaria* and *Panopeus herbstii* can be labelled using Rb as a marker. The rapid decline in the amount of Rb detected is the most serious shortcoming of the technique. However, this basic technique has many advantages including being an inexpensive, fast and easy method of marking many molluscs. Also, the prepared samples can be read qualitatively at a rapid rate, more than one sample per minute. It is unlikely

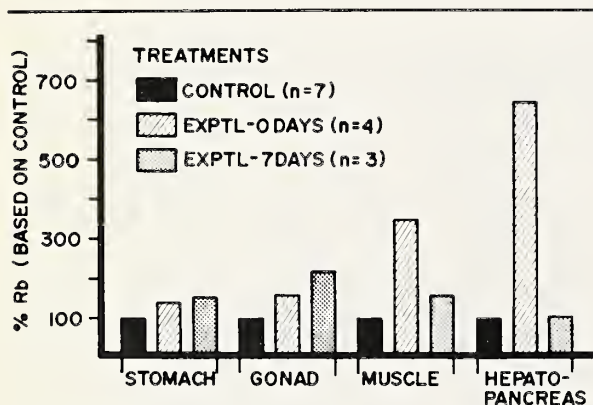


Figure 1. Amount of Rb in four tissues dissected from control and experimental crabs expressed as percentages (index numbers) of the control. Histograms are plotted for the control and experimental treatments at 0 and 7 days post-treatment.

that Rb would be used to mark long-lived clams in culture because of the rapid decline in detectable amounts of Rb, but Rb might well be used over shorter time periods before body burden of Rb levels off. Substituting similar non-radioactive trace elements for Rb, these basic techniques for labelling clams could be used to trace energy flow in clam culture systems.

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MOLLUSKS AS PREY OF ARIID CATFISH IN THE FLY RIVER

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Reasons for the examination of the contents of fish stomachs have varied over the years and with the interests of the people involved. In the early 1800's, fish stomachs were a common source of deep-water marine mollusks not easily obtained by other means at that time. Commercial fishermen were encouraged to save stomachs when they gutted their fish at sea and the boats were eagerly met as they came into port. The literature of that period often records descriptions of new species with the type locality given as the stomach of a fish caught off Gloucester or some other point.

In recent years there has been considerable interest in the feeding habits of fish, including those found in freshwater. This is evidenced, for example, in the fish section of the Zoological Record for 1971, which

references 74 authors under the heading *Mollusks as food* and covers 53 families of which 27 are either anadromous or freshwater. Though many papers have been published on the biology and feeding of freshwater fish, few do more than mention the relative importance of mollusks as food or, at best, identify the mollusk to genus. Bottom feeding freshwater fish such as the ariid catfish are an excellent source of mollusks and often allow one to obtain material from large rivers which otherwise would be difficult to collect. For example, the most abundant fish in the mainstream rapids of the lower Congo (now Zaire) River, is the cichlid *Steatocranus gibbiceps* Boulenger 1889 which feeds mainly on the small gastropods clinging to the rocks. It ingests the little-known assimineid *Septariellina congolensis* Bequaert and

Clench without crushing them so that perfect specimens may be taken from their stomachs. Both the fish and the mollusk are endemic to these rapids (Bequaert and Clench, 1936; Roberts and Stewart 1976). In the introduction to their paper on the rheophilous mollusks of the channel, Bequaert and Clench stated that:

1) the Congo River between Matadi and Boma courses through the narrow rocky channel at speeds ranging from 5 kilometers (low water) to 20 kilometers (high water) per hour; 2) the 6 species of snails found were all collected in February when the river was at its lowest; 3) "notwithstanding this favorable circumstance, the search for minute snails, with hand-lens in bright sunlight, on the moist surface of rocks, was most tedious and not without danger. Of the six species of snails, three were taken in single specimens only." and 4) "it may therefore be safely predicted that many other unusual finds await the skill and efforts of the malacologist in the Matadi-Boma channel of the Congo." It is obvious that fish adapted to feed on these snails have a much easier

time collecting and are a good source of specimens.

Species of the pangasiid catfish genus *Helicophagus* Bleeker 1858 inhabit the large rivers of Thailand and Sumatra, and, according to Smith (1945), the genus is well named. He reported that, though his specimens were collected at different places and different times, they all "had entire shells of small univalves in their stomachs." Unfortunately, the snails were not identified.

The present paper, concerned with the molluscan prey of the aniid catfish *Cinetodus froggatti* (Ramsay and Ogilby 1887) in the Fly River, New Guinea, demonstrates the value of collaboration between ichthyologists and malacologists. *Cinetodus* is a monotypic genus endemic to the rivers of southern central New Guinea. *Cinetodus froggatti* (Plate 1) occurs in the lowland riverine habitats of the upper, middle and lower Fly River (Plate 2) and has also been taken in the Kikori River (Kailola, 1975). Its feeding habits were unknown until Roberts collected a total of 16 specimens during an ichthyological survey of the Fly River in 1975 (Roberts, in press).

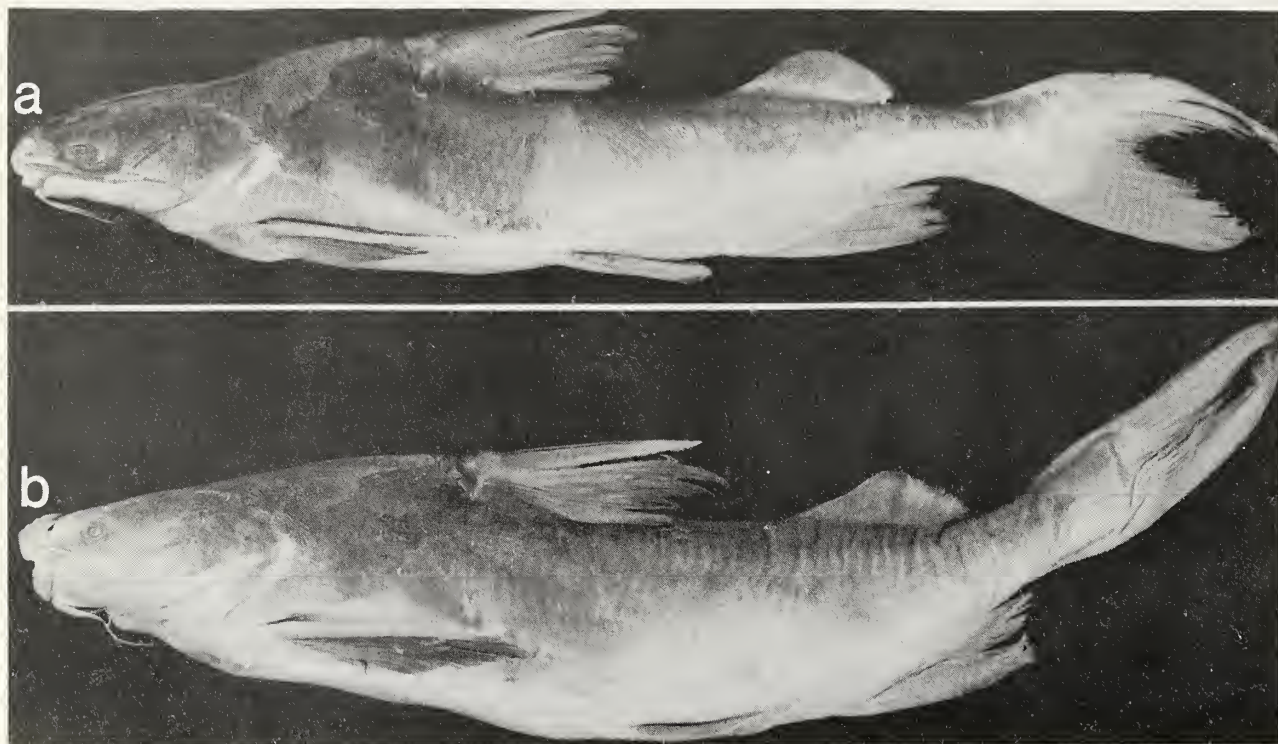


Plate 1. *Cinetodus froggatti*, Fly River station 26, USNM 217080. a: with normally developed lips and barbels (standard length 350 mm); b: with thickened

lips and barbels (standard length 320 mm). (from Roberts, in press).

TABLE 1
Species of Mollusks taken from
the stomachs of *Cinetodus froggatti*

Gastropoda	Station	No. of Specimens	Plate	fig.
Family Neritidae Lamarck 1816				
<i>Neritodryas simplex</i> (Schepman 1919)	1	3	3	1-3
	26	1		
Family Viviparidae Gray 1847				
<i>Bellamya decipiens</i> (Tapparone-Canefri 1883)	6	12	3	6-9
	25	1		
	26	1		
<i>Larina</i> sp.?	1	6	3	10-13
	20	+40		
Family Hydrobiidae Troschel 1857				
<i>Clenchiella sentaniensis</i> Jutting 1963	26	28	3	4-5
Family Bithyniidae Walker 1927				
<i>Gabbia lacustris</i> Jutting 1963	1	13	3	14-16
	26	14		
Family Assimineidae H. & A. Adams 1858				
<i>Acmella parvicostata</i> Jutting 1963	25	1	5	5
Family Thiaridae Gray 1847				
<i>Thiara scabra</i> (Muller 1774)	20	13	4	11-17
	25	1		
<i>Melanoides flyensis</i> (Tapparone-Canefri 1883)	1	6	4	6-8
	25	+35		
<i>Melanoides tuberculatum</i> (Muller 1774)	1	+60	4	1-5
<i>Tarebia granifera</i> (Lamarck 1822)	1	1	4	18-19
Family Planorbidae Rafinesque 1815				
<i>Amerianna carinata</i> (H. Adams 1861)	26	9	5	4
<i>Physastra vestita</i> (Tapparone-Cenfri 1883)	26	7	3	17-18
<i>Hippeutis</i> (<i>Helicorbis</i>)				
<i>umbilicalis</i> (Benson 1836)	26	2	5	1-3
Bivalvia				
Family Erodontidae Winckworth 1932				
<i>Erodona</i> sp.	26	26 valves	6	1-6

TABLE 2 - STATION DATA

Data are from Tyson Roberts' field notes. Station numbers (e.g. Fly 75-1) are those used for the fish collection, the 75 indicating the year of collection. We used only the last numbers on the map (Plate 2).

Fly 75- 1. Date: Oct. 1975.

Fish: *Cinetodus froggatti*, [USNM 217078].

Mollusks: *Neritodryas simplex*, *Larina* sp., *Gabbia lacustris*, *Melanoides flyensis*, *M. tuberculatus*, *Tarebia granifera*.

Location: Mainstream of Upper Fly River near Kiunga, 828 km. upriver from mouth of Fly, 6°07.7'S, 141°17.0'E. Water temp: 25.0-25.5°C; pH 7.1-7.4 on November 15, 1975.

Fly 75- 6. Date: Oct. 1975.

Fish: *C. froggatti*. [not preserved]

Mollusks: *Bellamya decipiens*.

Location: Ox-bow lake from mainstream of Fly River 3 km downstream from Kiunga.

Fly 75-17. Date: Nov. 23, 1975.

Fish: *C. froggatti* [USNM 217079]. 2:330-391 mm.

Mollusks: None — stomach empty.

Location: Mouth of Binge River, a large strongly flowing tributary of the Middle Fly, 675 km upriver from mouth of Fly, 6°32.5'S, 140°55.0'E.

Fly 75-20. Date: Nov. 27, 1975.

Fish: *C. froggatti*. [not preserved]

Mollusks: *Larina* sp., *Thiara scabra*.

Location: Mainstream of Middle Fly River near Boset, 509-512 km upriver from mouth of Fly, 7°14.0'S, 141°08.3'E.

Fly 75-25. Date: Dec. 6-7, 1975.

Fish: *C. froggatti*. [not preserved]

Mollusks: *Bellamya decipiens*, *Acmella parvicostata*, *Thiara scabra*, *Melanoides flyensis*.

Location: Grassy side channel and mainstream of Strickland River 2-3 miles downstream from Massey Bakers junction (junction with Herbert R.).

Fly 75-26. Date: Dec. 8, 1975.

Fish: *C. froggatti*. [USNM 217080]. 10:230-367 mm.

Mollusks: *Neritodryas simplex*, *Bellamya decipiens*, *Clenchiella sentaniensis*, *Gabbia lacustris*, *Americanna carinata*, *Physastra vestita*, *Hippeutis (Helicorbis) umbilicalis*, *Erodona* sp.

Location: Mainstream of Lower Fly River near Elangowan Island, 298 km upriver from mouth of Fly (about 50 km above uppermost influence of tides), 7°49.4'S, 141°39.0'E.

Fly 75-29. Date: Dec. 12, 1975.

Fish: *C. froggatti* [USNM 217081]. 1:423 mm.

Mollusks: None. Gut filled with mud.

Location: Lower 5 km of Burei Creek, a large tributary of the Lower Fly, 206-211 km upriver from mouth of Fly. 8°11.8'S, 142°00.7'E. Water clear, reddish brown.

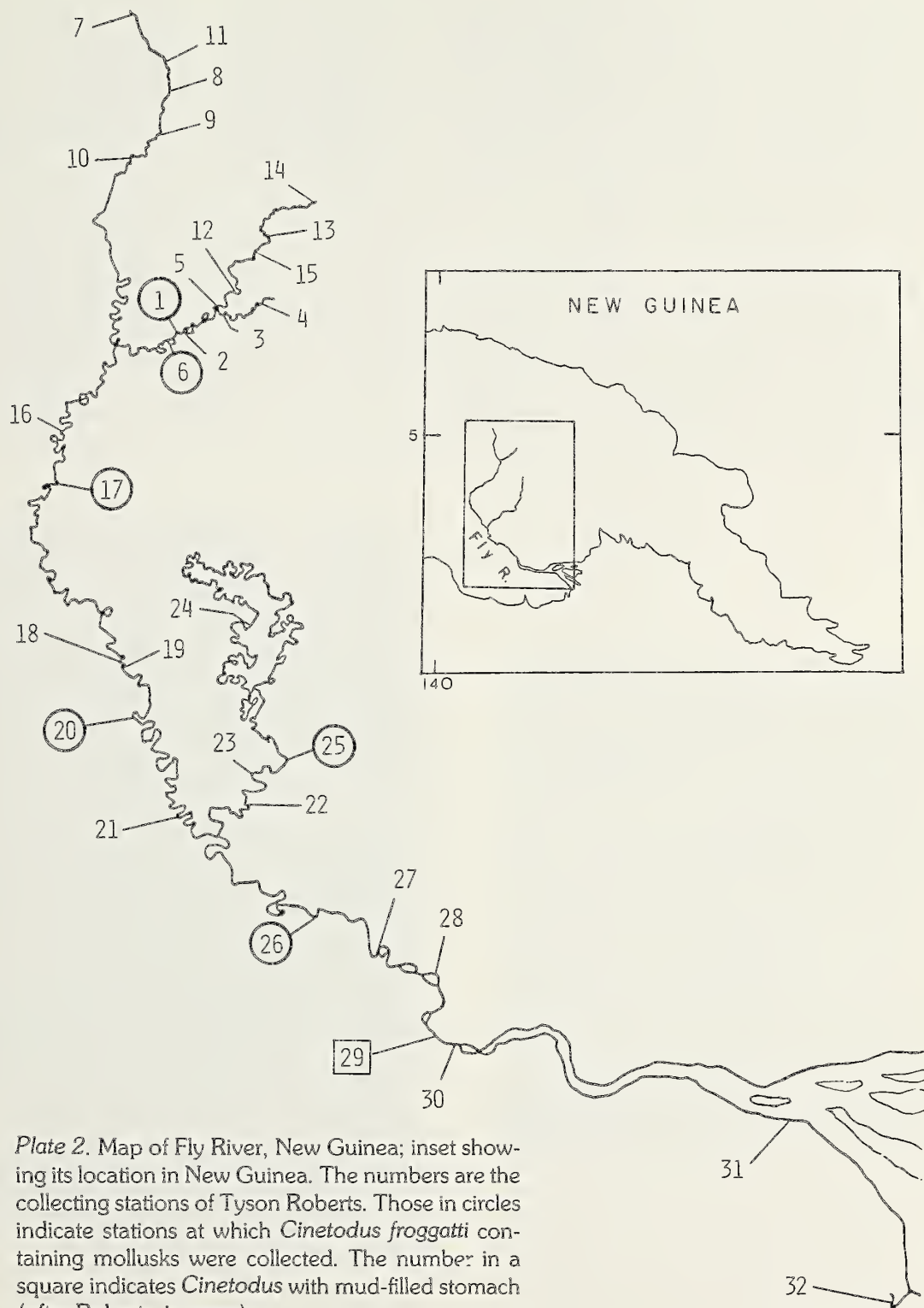


Plate 2. Map of Fly River, New Guinea; inset showing its location in New Guinea. The numbers are the collecting stations of Tyson Roberts. Those in circles indicate stations at which *Cinetodus froggatti* containing mollusks were collected. The number in a square indicates *Cinetodus* with mud-filled stomach (after Roberts, in press).

The contents of the digestive tracts of all specimens were examined and preserved, most of them while still in the field. Thirteen specimens had ingested numerous shelled mollusks, the shells of which were still intact, but little or no substrate; the guts of two were empty; and one, from station 29, had the stomach and anterior portion of the intestine filled with a thick, silty mud, devoid of macroscopic organic material. No other food items were observed.

Cinetodus froggatti apparently feed only on mollusks. However, as all collections were made from October through December, it is possible that at other seasons their diet could vary. The only other Fly River catfish feeding heavily on mollusks is the plotosid *Tandanus ater*. Unlike *Cinetodus* it crushes the shells it ingests and also feeds on insects, prawns and worms.

Cinetodus froggatti are typically found in the mainstream and large tributaries of the Fly River where there is a moderate to strong current, muddy bottom and a shoreline densely vegetated with grasses and other aquatic or semi-aquatic macrophytes. This was not true at station 29, on lower Burei Creek, the only site where the specimen's stomach was full of mud; here vegetation was lacking and the water was clear and reddish brown. Station 26 was 298 km from the mouth of the Fly River and about 50 km above the uppermost influence of the tides. At station 1, on November 15, the water temperature was 25.0 - 25.5° C and the pH 7.1 - 7.4. Reference should be made to Roberts (in press) for further ichthyological and ecological data on the Fly River.

Cinetodus froggatti is a small-mouthed anrid, distinguished from all other members of the family in having the ventral portion of the gill membranes broadly joined to a flat, broad isthmus, so that the gill openings are restricted to the sides of the head, possibly an adaptation to its diet. The gill rakers, gill arches, and pharyngeal folds or valves seem to be morphologically generalized, without evident specializations for malacophagy, though the shape of the oral tooth bands is very distinctive (Roberts, in press). All but one of the *C. froggatti* collected have rather thin lips and barbels (Plate 1, Fig. a). However, a 320 mm specimen from station 26 has the entire lips and basal portions of the chin barbels markedly thickened and all of the barbels slightly shortened (Plate 1, Fig. b). In all other characters it agrees with typical *C. froggatti*. It is noteworthy that this was the only specimen which had bivalves in its

stomach, and it apparently fed exclusively on this bivalve (Plate 6).

Fourteen species of mollusks representing 13 genera in 8 families were obtained from the fish and of these 8 were found at Station 26. The single species of bivalve belongs in the Erodonidae, genus *Erodona* Bose 1801. Though erodonids are rare in collections, the single, thick-lipped specimen of *froggatti* from Station 26 apparently had no trouble collecting them. It is possible that this small *Mya*-like bivalve is common in the muddy bottom of large deep rivers. Erodonids, so far as known, are brackish water bivalves. Their presence at Station 26, which is said to be 50 km above the influence of the tides, may be accounted for by the fact that: 1) there is a salt water creep on the bottom, 2) this is a new species of freshwater erodonid, or 3) the fish had fed further down stream. The largest gastropod re-

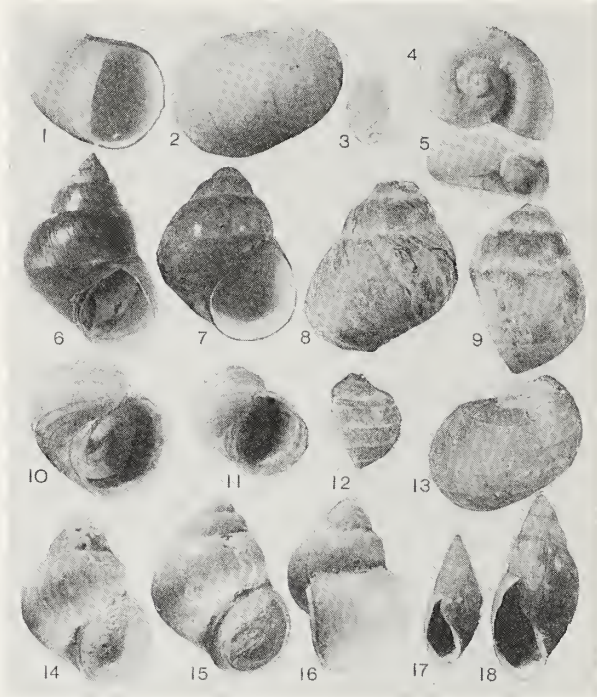


Plate 3. Figs. 1-3: *Neritodryas simplex* (Schepman). Sta. 1, (5X). Figs. 4-5: *Clenchiella sentaniensis* Jutting. Sta. 26, (12X). Fig. 6: *Bellamya decipiens* (Tapparone-Canefri). Sta. 25 (2X). Figs. 7-9: *Bellamya decipiens* (Tapparone-Canefri). Sta. 6, (2X). Figs. 10-13: *Larina* ? sp. Sta. 20, (3X). Fig. 14: *Gabbia lacustris* Jutting. Sta. 26, (10X). Figs. 15-16: *Gabbia lacustris* Jutting. Sta. 1, (10X). Figs. 17-18: *Physastra vestita* (Tapparone-Canefri). Sta. 26 (2X).

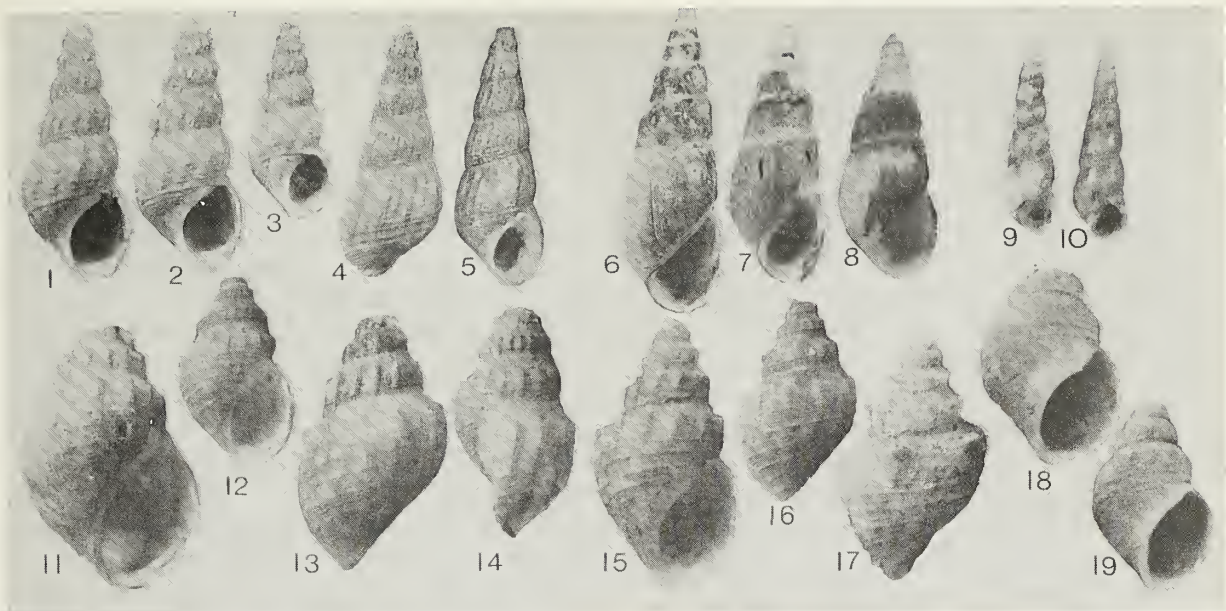


Plate 4. Figs. 1-5: *Melanoides tuberculatus* (Muller). Sta. 1, (2X). Figs. 6-8: *Melanoides flyensis* (Tapparoni-Canevari). Sta. 25, (2X). Figs. 9-10: *Melanoides* sp. Sta. 25, (2X). Figs. 11-14: *Thiara scabra* (Muller). Sta. 20, (5X). Figs. 15-17: *Thiara scabra* (Muller). Sta. 25, (5X). Figs. 18-19: *Tarebia granifera* (Lamarck). Sta. 1, (5X) (young).

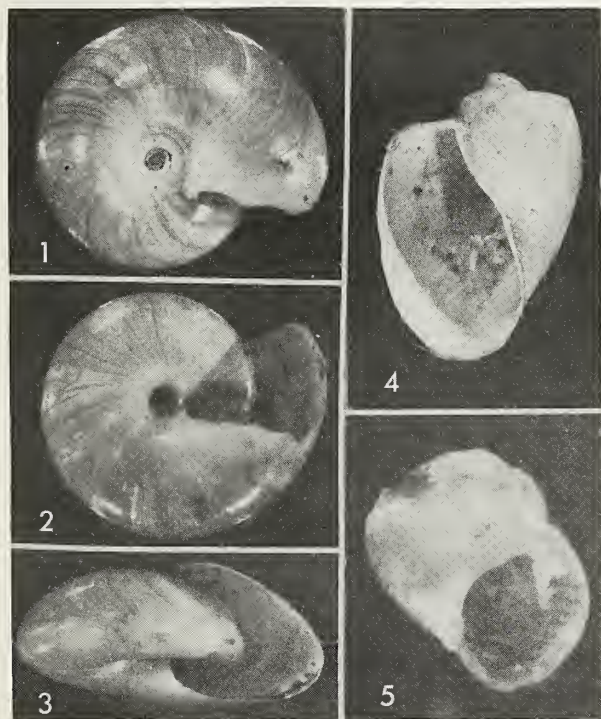


Plate 5. Figs. 1-3: *Hippeutis (Helicorbis) umbilicalis* (Benson). Sta. 26, (10.5X). Fig. 4: *Amerianna carinata* (H. Adams). Sta. 26, (10X). Fig. 5: *Acmella parvicostata* Jutting. Sta. 25, (32X) (young).

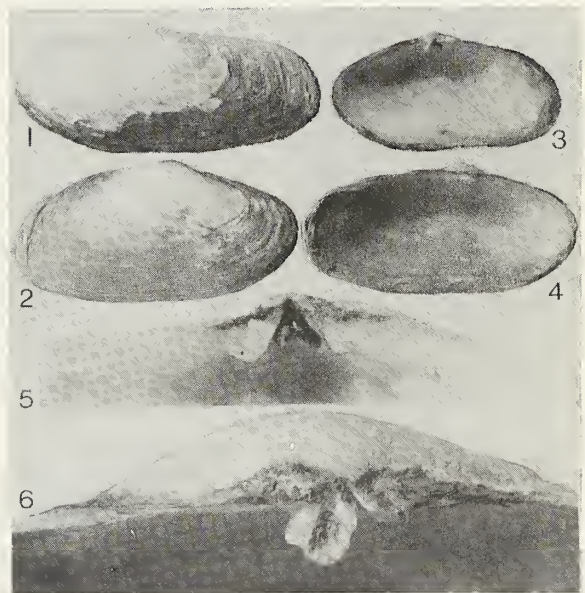


Plate 6. *Erodona* sp. Fig. 1: Outer view of left valve, (2X). Fig. 2: Outer view of right valve, (2X). Fig. 3: Inner view of right valve, (2X). Fig. 4: Inner view of left valve, (2X). Fig. 5: Close-up of hinge area of right valve, (4X). Fig. 6: Close-up of hinge area of left valve, (4X).

moved from a fish was 22 mm in length. The most common species found in *Cinetodus* stomachs were *Melanoides tuberculata*, *Melanoides flyensis*, *Belamya decipiens*, *Larina* sp. and *Clenchiella sentaniensis*. All of these gastropods are known freshwater species.

Based on fish stomach contents, the impression that lowland streams in the Amazon and Congo basins are poor in mollusks compared with those of southeast Asia (Roberts, 1972) was reinforced by additional field work in the Congo in 1973 (Roberts and Stewart, 1976) and in Borneo in 1976. The present work suggests that mollusks are more diverse, more abundant and more important as fish food in the lowlands of the Fly River than in either the Amazon or Congo.

Table I lists the mollusks found in *froggatti* stomachs, the stations at which the fish were collected, the number of specimens, and a reference to the illustrations.

Table II gives station data for those stations at which *Cinetodus froggatti* were collected.

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CORBICULA FLUMINEA (BIVALVIA: SPHAERIACEA): THE FUNCTIONAL MORPHOLOGY OF ITS HERMAPHRODITISM

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INTRODUCTION

Evidence has been presented earlier (Kraemer and Lott, 1977) to show that *Corbicula* is evidently a simultaneous hermaphrodite. On the one hand, that finding corresponds to the known hermaphroditism of other sphaeriaceans, the freshwater fingernail clams, *Sphaerium* and *Musculium* (Heard, 1977). On the other hand, comprehensive investigations (van der Schalie, 1970) revealed that hermaphroditism is rare in indigenous species of unionacean freshwater mussels. In the U.S., many of the latter species are dwindling and/or being replaced by the introduced Asian clam, *Corbicula*. Clues to the

phenomenal spread of *Corbicula* across the U.S. thus may logically be sought in studies of its hermaphroditic reproductive processes.

In a discussion of methods for assessing the reproductive cycle in (marine) bivalves, Seed (1976, p. 20) lists five procedures before concluding, "Probably the most reliable information is that obtained from microscopic preparation of the gonad." The present, primarily histological study was undertaken for the purpose of discovering and evaluating maturational and seasonal changes not only in the reproductive organs of *Corbicula*, but in other organs related to the animal's reproductive process, as

well.

Helpful background studies on reproduction in bivalves are those of Galtsoff (1964) on dioecious *Crassostrea virginica* and Seed (1976), Bayne (1976), Gabbott (1976), Bayne, Widdows, and Thompson (1976) for *Mytilus* and *Modiolus*. Pertinent information is found in the review by Roosen-Runge (1977) of studies to date on spermatogenesis in the whole phylum of mollusks. Fundamental questions concerning labile sex determination and protandry in mollusks are evaluated by Hoagland (1978).

MATERIALS AND METHODS

Clams for this study were taken from *Corbicula* populations in the Arkansas River in central Arkansas, and from the Buffalo River, in northwestern Arkansas. Continuing observations of living *Corbicula* and dissections of fresh tissues accompanied this study. Data described and evaluated here however, are drawn primarily from the detailed analysis of more than 15000 serial sections of animals 2mm to 20mm long (sacrificed in July, August, September, January, and March). Histological material was prepared as described elsewhere (Kraemer and Lott, 1977). All animals were relaxed in Nembutal solution, fixed in Bouin's fluid, and were preserved in 70% ethanol. Most sections were sagittal, some frontal, and some transverse. An aniline blue variation of Mallory's triple staining technique was used (Schmitz, 1967). All stained material was saved. Comparison between sections showing typical differential staining and sections overstained or understained with alizarin red or with aniline blue — proved helpful in detecting consistent histological characteristics of the clams.

Photomicrographs were made with a 35mm Leica camera in conjunction with a Leitz Ortholux microscope equipped for bright-field transmitted light, and with a 35mm Wild MKa 1 camera in conjunction with a Wild M5 stereomicroscope.

Tissues examined in this study were primarily those of the visceral mass. Orientation of the visceral mass within the animal is shown in Fig. 1.

RESULTS

In this study evidence has emerged for the existence of a specific reproductive complex in *Corbicula*, comprised of both maturational and seasonal changes in the animal's tissues, and involving the digestive, reproductive and nervous systems.

The Digestive Glands

In many specimens examined in this study, the epithelium of the digestive glands was low, cuboidal. The glands as a whole exhibited a branching, spread out appearance. The peripheral, blind-ending tubules showed a "cross" shaped lumen, similar to that described by Galtsoff (1964) for *Crassostrea virginica*.

In some specimens the greatly enlarged epithelial cells of the glands nearly occluded the glands' lumina. The overall appearance of the glands was crowded, compacted, (Fig. 2A). The digestive glands of "normal" or "swollen" appearance were found in both small (2mm long) and larger (20mm long) clams. At all times, digestive gland epithelium contained at least two types of cells: (1) triangular, granular, basophilic cells and (2) more slender, acidophilic cells: appearance of the stained digestive gland epithelium was thus consistently "blotchy" rather than homogeneous (Fig. 2A).



Figure 1. Drawing of *Corbicula fluminea*, with left shell valve, left lobe of mantle, and most of left pair of gills removed, to display the visceral mass. AA, anterior adductor muscle; CG, cerebral ganglion; CT, location of cardinal teeth in right valve; CV, cerebro-visceral connective; EG, cut edge of (removed) gills; F, foot; LP, labial palp; M, mantle; PA, posterior adductor muscle; PM, pedal muscle; VG, visceral ganglion; VM, visceral mass. (Drawing made from fresh tissues.)

Digestive glands of marine mussels are known to be involved in intracellular and extracellular digestion. Bayne, Widdows and Thompson (1976), Owen (1972, 1966), Purchon (1971), Morton (1971) observe that the digestive glands of intertidal bivalves may manifest rhythmical cycles of intracellular digestion (ostensibly by means of the columnar, acidophilic, pale-staining cells) and extracellular digestion (basophilic, triangular cells). Bayne *et al* also review findings of several workers which indicate that the digestive glands (1976, p. 151), "... serve as a site for the storage of metabolic reserves which provide a source of energy utilized during gametogenesis and during periods of physiological stress."

In this study of *Corbicula*, the swollen-appearing digestive glands were often associated with a stroma containing few or no gonadal follicles. This observation was made on tissues prepared from both small and larger clams. It seems plausible that the swollen phase of the digestive glands is a storage period, preceding and coinciding with early seasonal development of the gonads (Fig. 2A).

A frequent observation made in this study was an intimate morphological association between the digestive glands and the developing gonads. Often the latter were immediately adjacent to submucosal connective tissue of the digestive gland, and appeared to be joined to it.

Reproductive Organs and Associated Structures

A. Reproductive structures in small clams: Serial sections of all tissues of 12 small (2-3mm) animals were carefully examined. In all of these animals, the gonoducts are already differentiated and distinct. In small animals showing "normal" digestive glands (i.e. with low cuboidal epithelium), the stroma of the visceral mass is comprised of sparse fibers and cells. In two small animals no sign of gonadal development is detected. In another, a study of all sections shows but a single strand of primordial gonadal tissue, immediately adjacent to the gut.

In small animals whose serial sections show "swollen" digestive glands, the stroma of the visceral mass is as above. Four to five long slender follicles appeared immediately peripheral to the gut and digestive glands. The former all show developing female gametes in a single row, attached to the wall of the follicle. In none of the small animals examined in this study are any sperm or spermatogenic follicles seen.

From this study it seems that when gonadal tissue first appears it may be "indifferent" (not specifically male or female). A number of authors have additionally argued, however, that in most hermaphroditic mollusks, differentiation of male gametes occurs first. Roosen-Runge (1977) reviews assorted conclusions and evidence (much of it from pulmonate gastropods) for this view. Yet certainly the first recognizable sex cells discerned throughout this study in young *Corbicula* are female sex cells.

B. Reproductive "Complex" in larger *Corbicula*: Serial sections of all tissues of 10 larger animals (8-20mm) were examined in this study. Certain phenomena involving digestive gland epithelia, female and male gonads, stroma of the gonads, and the nervous system were repeatedly observed. These phenomena may form the basis of a repro-

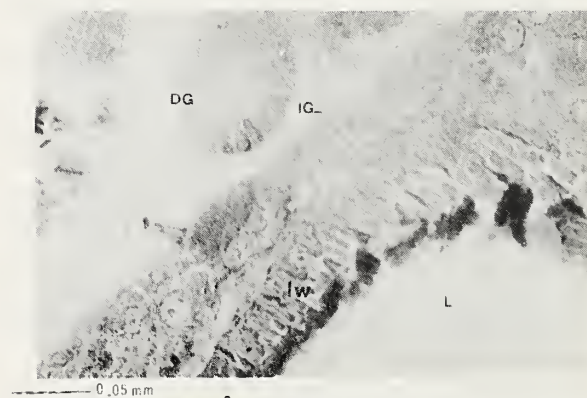


Figure 2. Early gonadal development in *Corbicula*. (2A) section showing development of gonad in close association with digestive gland. (2B) section showing development of gonad in close association with wall of intestine. DG, digestive gland; IG, incipient gonad; IW, intestinal wall; L, lumen of intestine.

ductive complex exhibiting the following sequence:

1) Epithelium of the digestive glands shows enlarged, "swollen" cells (described above). Stroma of the visceral mass is comprised of sparse strands of connective tissue and scattered cells. Primordial gonadal tissue appears as slender follicles in the stroma.

2) Five or six follicles, long and slender and containing developing egg cells are seen closely associated with the digestive gland and gut wall (Fig. 2A, B, and 3A). These follicles appear to share the submucosal membranes of the digestive tract.

3) Conspicuous areas of closely packed parenchymal cells appear in the stroma (Fig. 3B, C, D, E, F).

4) The gametogenic follicles, now obviously full of developing eggs, become more numerous, enlarge, and ramify through the stroma (Fig. 3B). Within the follicles, the developing eggs grow from and remain attached to the follicular membrane. As they grow larger the oogametes and their membranes crowd each other and assume rectangular or triangular shapes (Fig. 3C). Lumina of the female follicles are occluded. At this time a few spermatogenic follicles may be seen, usually peripheral to the oogenic follicles. These spermatogenic follicles do not typically contain mature sperm. The male follicles are always comparatively few and have a lobed, acinar appearance. They are continuous with, but appear as stubby end clusters at the tips of tubular female follicles.

5) Small branched clusters of male follicles appear which frequently contain bunches of sperm adhering (at their heads) to cells in the acinar wall (Fig. 5). A similar phenomenon, described by Archie in 1943 for the snail *Lymnea stagnalis* is reviewed by Roosen-Runge, (1977). In addition, spherical clusters of sperm occur in the acinar lumina, as described earlier (Kraemer and Lott, 1977). Male follicles typically occur in four (paired) sites in the visceral mass: (a) in the posterior-ventral portion of the visceral mass, adjacent to the large ventral loop of the intestine, and next to the body wall; (b) in the midoventral portion of the visceral mass, above and lateral to the pedal ganglion; (c) in the mid-anterior region of the visceral mass, just posterior and dorsal to each of the cerebral ganglia; (d) in the mid-dorsal region of the visceral mass, close to the cerebro-visceral connectives and to the gonoducts (Fig. 1).

6) Later changes in the oogenic follicles:

(a) The epithelium of the female follicles, initially composed of low cuboidal cells, thins. Female

gametes no longer crowd each other, but still fill the lumina of the follicles, assume bizarre shapes and often are seen attached to the follicular epithelium by long peduncles. The gametes thus look as though they were being stretched or pulled from their moorings (Fig. 3D).

(b) Many of the follicles show large empty lumina. Many of the gametes remaining are large, irregularly shaped. Some follicles show immature female gametes. This phase appears to be a spent phase of the gonad. Within a number of the follicles clusters of cells resembling embryos are seen (Fig. 3F). A summary of the stages observed in the female follicles of maturing *Corbicula* is shown in Figure 4.

7) Later changes in the spermatogenic follicles:

(a) Compound acini of spermatogenic follicles are seen primarily in the four locations indicated above. These follicles typically show spherical and/or hemispherical masses of mature sperm (Fig. 5).

(b) Associated with the four testicular sites is one (or a pair) of "new" structures described as follows (Fig. 6):

(i) Each contains one or two clusters of pale, pear-shaped cells which closely resemble the soma of neurons (Fig. 6A, B, C, D).

(ii) Each contains a fibrous central core resembling the neuropil of a ganglion (Fig. 6B, C, D).

(iii) Each contains one or more cavities, lined with very regular ciliated cuboidal epithelial cells. These cavities may contain some stained amorphous material (Fig. 6D).

(iv) Each possesses a thick stalk which suspends the structure within the conjoined lumina of several spermatogenic follicles. This cavity often adjoins the lumina of several oogenic follicles (Fig. 6B).

(v) Each possesses a twisting mass of fibrous tissue having the appearance of a small knot of nerves (Fig. 6B, C, D).

(vi) Each is innervated by nerve fibers branching through the stroma from one of the major ganglia or connectives (Fig. 6A).

Usually the most prominent of the peculiar structures described above are those which are associated with the posterior ventral portion of the visceral mass, and apparently are innervated by small pedal nerves. What are these structures? Why are they seen *only* when spermatogenesis is well advanced in *Corbicula*? What is the significance of their nerve supply and their obvious resemblance to ganglia?

In the literature the closest fit I could find to the above described structures is from Roosen-Runge

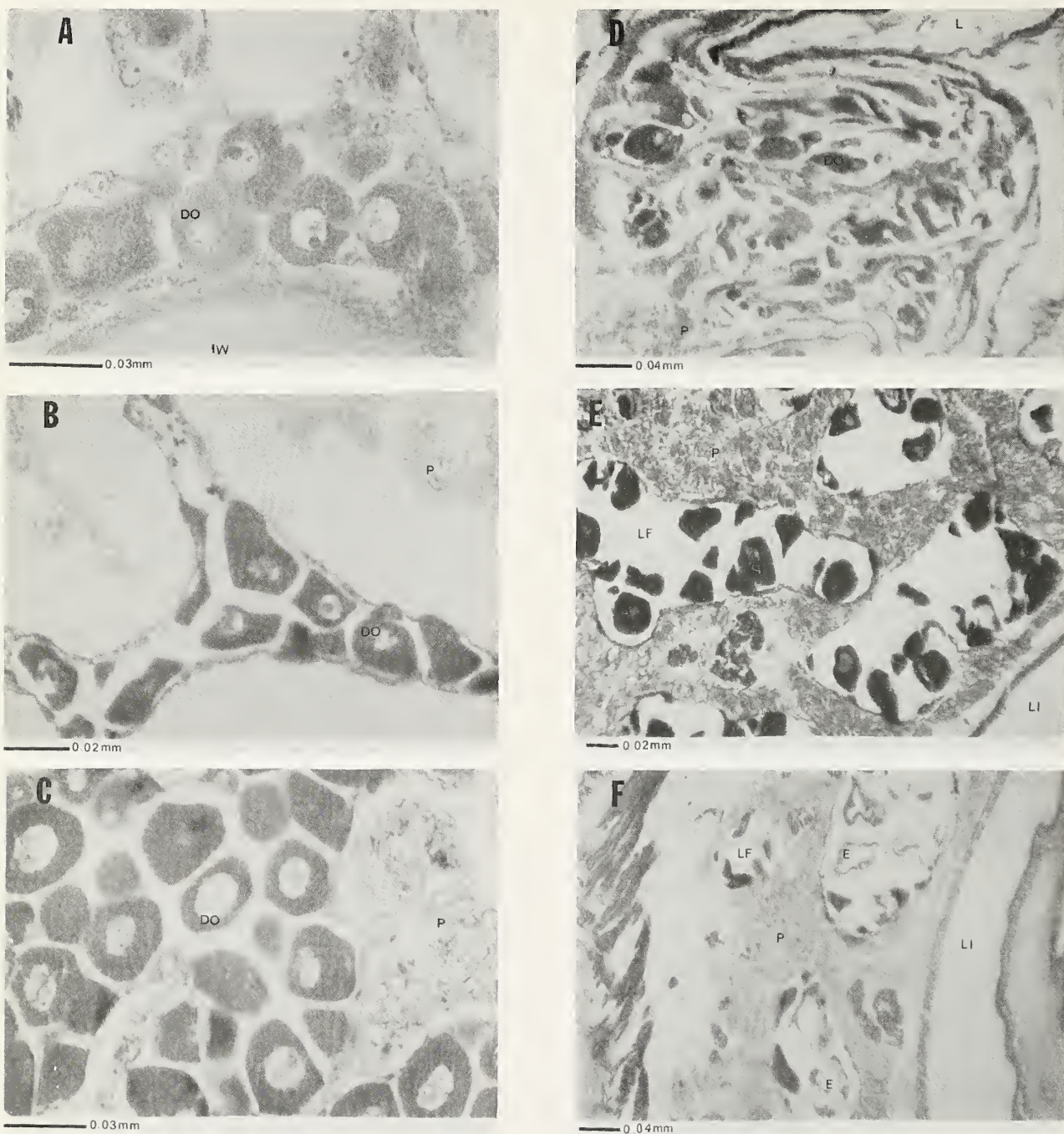


Figure 3. Development of oogenic follicles in *Corbicula*.

- A. Development of oogenic follicle in association with wall of intestine.
- B. Oogenic follicle branching through stroma of visceral mass.
- C. Later development of gametes which, with their separate, distinct membranes, crowd the lumina of the follicles.
- D. Oogenic stage in which gametes stretch from

long peduncles.

E. Late stage in which follicles appear fairly empty. Note dense parenchyma.

F. Final stage in which structures resembling young embryos appear.

DO, developing oocyte; IW, intestinal wall; P, parenchymal cells (of stroma) of visceral mass; L, lumen of intestine; E, "embryo"; LF, lumen of follicle; LI, lumen of intestine.

(1977, p. 41) in reference to Archie's 1943 Ph.D. thesis on *Lymnea stagnalis*:

"a peculiar finding is the existence of secretory cells which appear only when spermatogenesis is already well-advanced. These are large, bulb-shaped cells extending into the lumen by a cytoplasmic stalk and containing 6-120 round bodies which stain lightly and variably with iron-hematoxylin. The nuclei resemble those of nurse cells. They are polymorphic and possess a large (diameter 2.6μ) nucleolus."

Note that the foregoing contains no mention of enclosed nerve fibers or of innervation. Archie's

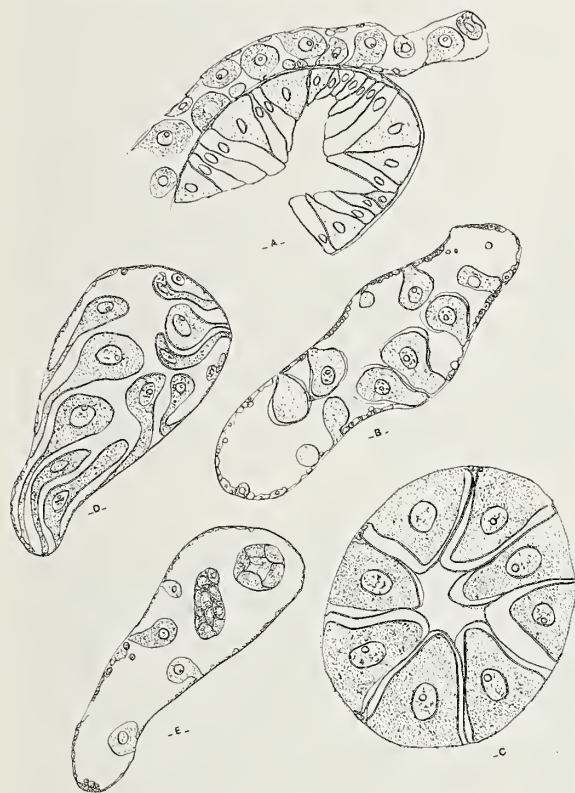


Figure 4. Summary of apparent sequence of stages in development of oogenic follicles in *Corbicula*. (A) early development of follicle, contiguous with digestive gland. (B) enlarging of follicle, growth of oocytes. (C) growth of oocytes to crowd lumen of each follicle. (D) stretching of oocytes from long peduncles. (E) emptying of follicle; appearance of putative "embryos" in lumen. Compare (A) with Figures 2A, 2B and 3A; (B) with Figure 3B; (C) with Figure 3C; (D) with Figure 3D; and (E) with Figures 3E, 3F.

staining and/or fixation technique could have precluded his making such observations. The Mallory's process used for *Corbicula* in this study, however, is adequate for visualizing small nerve fibers in the tissues. After confirming the morphological details of more than 50 of these "new" structures in *Corbicula*; and after a literature search which turned up only the above reference; I have tentatively concluded that a suitable name for each of these structures is *follicular ganglion*. It seems possible that such follicular ganglia may be found in other mollusks as well. They may function in co-ordination of the gametogenic and/or fertilization process of hermaphroditic mollusks. These follicular ganglia will be discussed further below.

(c) Spermatogenic follicles are conjoined with oogenic ones. Frequently mature sperm and eggs will be found together within the conjoined lumina (Fig. 5).

(d) Finally, small masses of cells resembling embryos are also frequently encountered within the lumina of follicles near the follicular ganglia.

8) *The gonoducts*: Paired gonoducts were well defined in the smallest specimens (2mm) examined in this study, even in those lacking gonadal tissue. In the larger specimens, two long oogenic tubules (one dorsal and horizontal, one posterior and vertical)

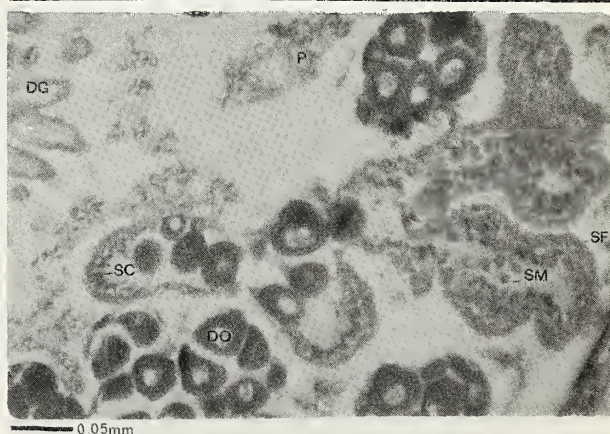


Figure 5. Sagittal section of visceral mass of *Corbicula* showing spermatogenic follicles developed peripheral and contiguous to maturing oogenic follicles. DG, digestive gland; DO, developing egg cell; P, parenchyma cells (of stroma) of visceral mass; SC, sperm clusters (attached by sperm heads to follicular cells); SF, spermatogenic follicle; SM, sperm "morulae" or spheres of sperm in lumen of spermatogenic follicle.

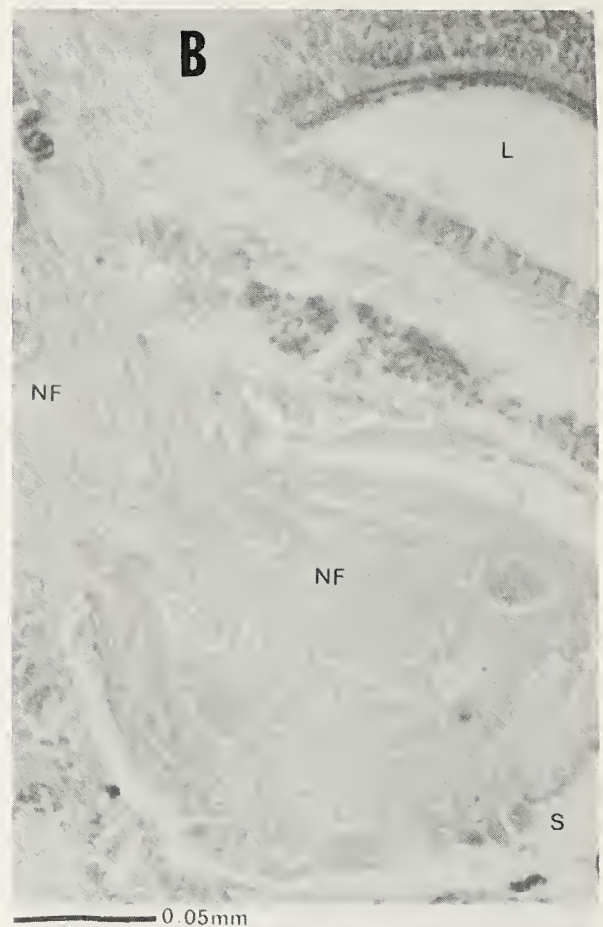
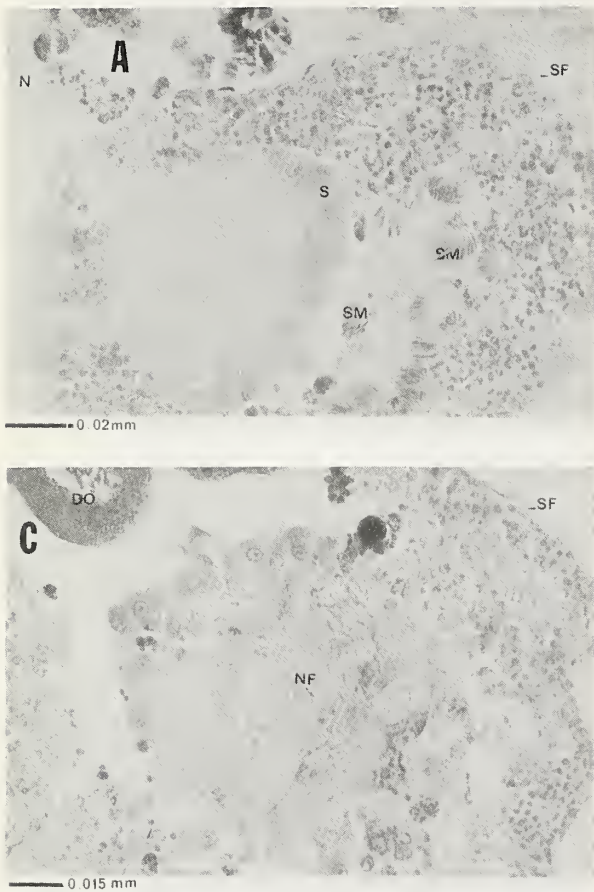
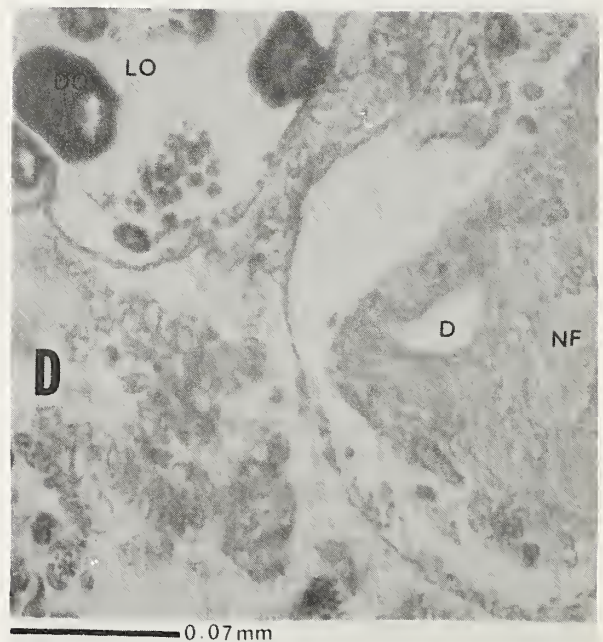


Figure 6. Structural detail of the "follicular ganglia" of *Corbicula*.

- A. "Follicular ganglion" from anterior region of visceral mass, posterior and slightly dorsal to a cerebral ganglion. Note the many neuronal-soma-like cells at its periphery, and its location within a well-developed spermatogenic follicle.
- B. "Follicular ganglion" from mid-ventral region of visceral mass, showing nerve fibers in its core and stalk.
- C. Section of "follicular ganglion" showing its characteristic location at a confluence between spermatogenic and oogenic follicles.
- D. Section of "follicular ganglion" showing core of nerve fibers and duct.

L, lumen of intestine; N, nerve (from cerebral ganglion); NF, neuronal fibers; SF, spermatogenic follicle; SM, sperm "morulae" in lumen of spermatogenic follicle; DO, developing oocyte; LO, lumen of oogenic follicle; P, parenchyma cells (of stroma) of visceral mass; S, cells with appearance of unipolar neuronal soma.



converge near and open into the gonoduct on each side of the animal. The lips of each short duct are covered inside and out with ciliated columnar epithelium.

A pair of connectives from the fused visceral ganglia to each of the cerebral ganglia penetrates the visceral mass on either side — right at the outer edge of each gonoduct. Small nerve fibers can be seen extending from each connective to the gonoduct mucosa (Fig. 7). This innervation pattern was a consistent feature of all of the 6mm or larger animals studied. This observation was not made on the smaller (2-3mm) *Corbicula*.

9) *Embryos*: In the course of this study, cell aggregates of apparent blastomeres were found in the lumina of a number of mature follicles (Fig. 3F). I found this observation puzzling partly because the

"embryos" were never as numerous as the developing egg cells around them.

In this study also, several sagittal and frontal sections of clams containing embryos in inner gill compartments were studied. In one specimen the embryos were scarcely further developed than the intrafollicular "embryos." The other gravid *Corbicula* contained pediveliger larvae, laterally compressed and bivalve, with adductor muscle, ligament, visceral mass and kidney tubules. Serial sections showed these well-developed larvae occupying positions in most of the water tubes of both inner gills, from the anterior to the most posterior chambers. While it seems increasingly likely that self-fertilization, even intrafollicular fertilization may take place in *Corbicula*, I do not feel sufficient evidence for this has been presented here.

SUMMARY, DISCUSSION AND CONCLUSIONS

In this study of more than 15000 serial sections of more than 20 *Corbicula* varying in length from 2 to 20mm, I have found:

1. The *Corbicula* oogenic follicles develop and mature well before spermatogenic follicles do.
2. Changes in the digestive glands' epithelium accompany the appearance and gradual development of the visceral mass stroma and of the oogenic follicles.
3. Development of spermatogenic follicles occurs at branching ends of the earlier-appearing oogenic follicles.
4. Maturation of the spermatogenic follicles is accompanied by development of "new" structures herein described and named *follicular ganglia*.
5. With the development of follicular ganglia, masses of mature sperm are present in the surrounding follicles. Oogenic follicles show female gametes of bizarre shape, stretched from their epithelial attachment sites by long peduncles. Many of the female gametes are mingled with mature sperm. A number of oogenic follicles then appear empty or spent. Finally a number of the follicles contain what appear to be young embryos.

6. The follicular ganglia and the lips of the gonoducts are innervated by nerves or connectives from the main ganglia of the animal.

7. Early embryos as well as later periveligers come to occupy nearly the total length of the interlamellar space in both inner gills.

Two potentially problematic findings emerge from this study. One is that careful study of thousands of

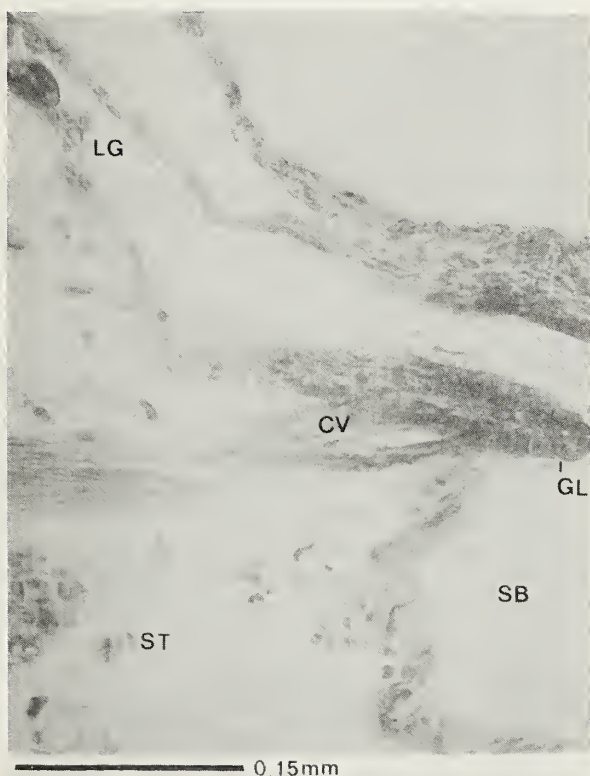


Figure 7. Sagittal section of *Corbicula* through region of gonoduct, showing innervation of gonoduct lip by means of fibers from the ipsilateral cerebrovisceral connective (see also Fig. 1). CV, cerebrovisceral connective fibers innervation lip of gonoduct; GL, gonoduct lip; LG, lumen of gonad; SB, suprabranchial cavity; ST, stroma of visceral mass.

serial sections of *Corbicula* invariably revealed the first recognizable sex cells to develop from undifferentiated gametogenic cells – are developing egg cells. Also, growth in size and number of oogenic follicles occurs in small *Corbicula* (2-3mm) which possess well differentiated gonoducts but no evidence of spermatogenic follicles. Spermatogenic follicles containing mature sperm are not seen except in the larger *Corbicula*, and then only when there has been much growth and development of oogenic follicles. Finally, spermatogenic follicles characteristically are located peripherally to the oogenic ones, and (as reported earlier by Kraemer and Lott, 1977) are always far fewer in number. Beklemishev (1959) notes that Pelseneer in 1895 contended all hermaphrodites are probably initially female. A number of endocrinologists (William Money, personal communication) hold that all sexually reproducing animals can probably be considered as females, upon which "maleness" may be superimposed. Whether or not such a principle is generally true, the characterization does seem to fit observations made on *Corbicula* in this study.

How does one integrate the "femaleness" of *Corbicula* with Hoagland's (1978) careful evaluation of labile sex determination and protandry in mollusks? Certainly the protandrous studies she has done are impressive. Might it be simply that the early differentiation of oogenic follicles seen here in *Corbicula* is just further evidence of the remarkable developmental plasticity of mollusks?

The other problematic finding from this study is that spermatogenesis in *Corbicula* is associated with the differentiation of complex innervated structures which I have called follicular ganglia. Since these structures have been found and the details of their structure have been determined dozens of times in the tissues evaluated for this study – it seems likely that similar follicular ganglia must exist in other mollusks. Why haven't they been described previously? The follicular ganglia are small and require study by means of serial sections and appropriate staining techniques – and thus may simply not have been observed before.

The bivalve nervous system does manifest a good deal of plasticity in its structure. Neuronal soma are not confined to the central ganglia but string out along connectives and nerves and may cluster as tiny ganglia at the mantle periphery, etc. Accessory mantle ganglia associated with spawning activity in

certain freshwater unionid mussels have been described elsewhere.

A number of questions still require investigation. One of these is the elusive matter of possible internal self-fertilization and early internal development of embryos. Another concerns possible functions of the follicular ganglia. Details of oogenesis and spermatogenesis are unstudied. The matter of "nurse" cells within the gonads – studies of which have concerned other workers (Roosen-Runge, 1978) on mollusks – have not been dealt with here.

Larger questions related to reproduction in *Corbicula* remain: What are the timing mechanisms for maturation of the female and male gonads? Is it possible that some members of a *Corbicula* population have a different reproductive role from others? (e.g. Do some actually function just as females? Are these parthenogenetic individuals?)

Many of these questions will obviously require attack by means of techniques other than those used in the present study.

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BIANNUAL GAMETOGENESIS IN MARGARITIFERA MARGARITIFERA (L.) IN NORTHEASTERN NORTH AMERICA

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Among studies concerning the reproductive periods of mollusks, the best evidence (comparative) for biannual reproduction versus annual reproduction comes from commercially important marine bivalves. Giese (1959) has discussed the effects of latitude on general reproductive patterns of bivalve mollusks as well as other marine invertebrates. His survey concludes that, although exceptions exist, in colder environments the reproductive period is short and typified by production of a single brood during the summer while in warmer seas two or more broods are often produced and reproductive periodicity is less confined to a specific climatic season. Gilbert (1978) recently summarized the findings on several marine species of bivalve mollusks occurring along the eastern North American coast which support Giese's (1959) conclusions.

Similar studies on freshwater bivalves are few and scattered. The available information on Sphaerian clams, which exhibit reproductive patterns much like pulmonate Gastropods (Russell-Hunter, 1964; Hermann and Harman, 1975; McMahon, 1975, 1976), has been analyzed and discussed by Heard (1977). These mollusks undergo uni- to multi-voltine annual recruitment cycles characteristic of short lived aquatic invertebrates (Patrick, 1975). Holarctic Unionacean bivalves do not conform to

the above diagnosis. Instead they are relatively long lived, late maturing animals (van der Schalie, 1970) and are most prevalent in running waters. As a result distinctive reproductive patterns have evolved including sustained iteroparity and complex brooding cycles (Ortmann, 1911; Heard and Guckert, 1971). Typically those species following a conventional bradytic or long term breeding strategy produce a single brood in the fall, which is maintained or incubated through winter and spawned the following spring. Recently, Heard (1975), working on bradytic Anodontine Unionaceans, has discussed evidence for year around asynchronous reproduction in *Anodonta imbecilis* and has shown that two other species of *Anodonta* engage in winter tachytictic or short term breeding cycles. A fourth species, *A. peggyae*, exhibits two reproductive cycles, spring through summer and fall through winter. Each of these examples occurs in semi-tropical or warm temperate regions and conform to Giese's (1959) format of reproductive patterns for those areas. The holarctic Unionacean family Margaritiferidae is considered to be composed of normally tachytictic forms. The principal species within the family, *Margaritifera margaritifera*, is confined chiefly to cold temperate and subarctic regions throughout its range (Walker, 1910). Gross and histological ex-

amination of populations in northeastern North America has shown that *M. margaritifera* partakes in a late summer-fall recruitment cycle (Smith, 1976) thus providing an initial modification to the typical tachytictic trait of short term spring reproduction. Additionally, investigation has revealed that secondary late winter gametogenesis also occurs. The present report discusses the presence and possible purpose of secondary gamete production in *M. margaritifera* and its implications on life history design in the species.

MATERIALS AND METHODS

Two streams containing populations of *M. margaritifera* were selected for analysis: Cushman Brook, Amherst, Massachusetts, and Joe Wright Brook, Williamsburg, Massachusetts. Both occur in the Connecticut River watershed. The two populations were analyzed at 10-day intervals from 24 January until 13 March 1978. Selection of populations for study was dictated by the degree of accessibility as many streams in the area were covered by ice. On each visit, 2 animals were retained for serial sectioning and staining of gonadal tissues, except in Joe Wright Brook where only alternate collections were made due to the reduced size of the population. A total of 16 specimens were thus collected and all are maintained in the Museum of Zoology, University of Massachusetts.

Gonad portions were removed from viscera, impregnated with paraffin and sectioned at 8 μ m. Sections were cleared and dehydrated through an alcohol series and stained with Harris' hematoxylin and eosin or fast green.

RESULTS AND DISCUSSION

Inspection of gonadal sections revealed that gametogenesis, in inspected populations, resumes in mid-winter following the fall spawning period. Gamete development was most pronounced in females in which many maturing ova were found entering the lumen of follicular acini. Males were producing typical male inclusions, such as spermatid and sperm morulae, however, prodigious amounts of adult sperm, seen in summer animals, were never evident although occasional males did contain large amounts of apparently mature sperm. During this period two animals, consisting 14 percent of the total sample, did not participate in gamete production. One individual was a female, the other unidentifiable.

Gradual maturation of ova was documented in successively collected animals (Fig. 1a) until late February when free ova suddenly decreased in number and showed loss of definition of nuclear components (Fig. 1b). Associated cell bodies in gonadal tissues became disrupted as well. From this point on females of each population produced no free ova, although attached developing oocytes were present. Nutritive material and sustaining cells became disorganized and the entire gonad assumed a typical spent appearance. Males followed suit somewhat.

From 26 February until 13 March periodic inspection of demibranchs for gravidness were made in each population. Between 7 March and 13 March a large sample comprising 20 specimens from each population was inspected. On neither occasion were specimens found with eggs or larvae in the demibranchs.

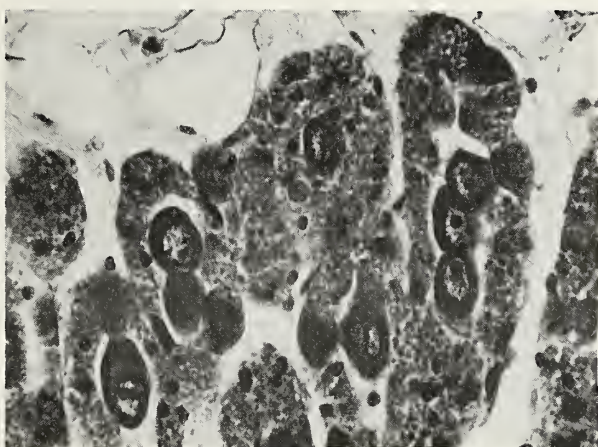
The question immediately arises regarding the purpose of winter gametogenesis in *M. margaritifera*. Prior studies by Smith (1976, unpublished data) have shown that all local populations undergo a uniform fall recruitment cycle and that adult individuals participate in the cycle. It is suggested that fall spawning in mussels is correlated with the activities and movements the brook trout, *Salvelinus fontinalis*, the natural host fish for glochidia of *M. margaritifera* (Smith, 1976).

In New England the brook trout breeds from September through December (Scott and Crossman, 1975) and during this period, when fish are aggregated over spawning grounds, *M. margaritifera* releases its glochidia larvae. Therefore, by spawning during the fall *M. margaritifera* can theoretically maximize the chance for glochidial attachment on fish thus enhancing larval survivorship. As with all other freshwater mussels extremely high juvenile mortality apparently occurs within *M. margaritifera* undoubtedly caused by the complex planktonic-infaunal early life history scenario.

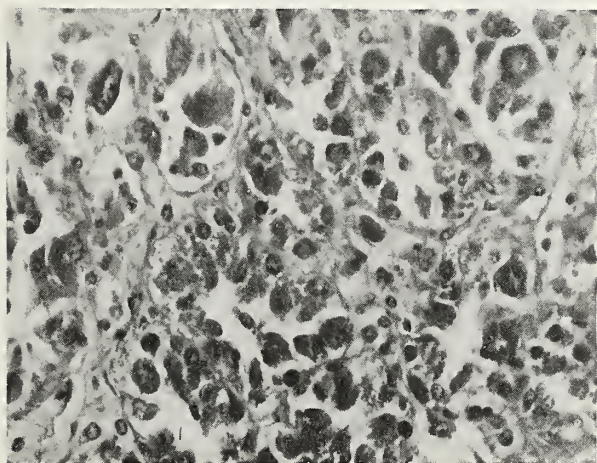
It is not known if the winter ova within the gonads are mature and ready for oviposition into the demibranchs. A comparison with summer-produced gametes shows that winter ova are much smaller and slower developing (Figure 2). However, Brousseau (1978) found that, in *Mya arenaria*, early spring reproduction involved smaller ova than summer production. Furthermore, in *M. margaritifera*, winter produced sperm appeared mature, even if not abundant. The reason for winter gamete production in *M.*

margaritifera unfortunately remains unclear. However, two possible motives are suggested. The first supposes a nutritive role for the winter gametes. Mollusks are limited in the types of energy storage bodies (Giese, 1969). The use of gametes for this purpose seems feasible. A logical use for energy stored during winter would be preparation for renewed growth and regular gamete production in spring. However, although the above functions are universal for all individuals, not all mussels undergo winter gametogenesis.

Another theory proposes that winter gamete production represents a relict of a former reproductive period involving spring or summer egg deposition and spawning. Knowing how close to maturity the



a



b

Figure 1. Portions of female gonads X90; a. 9 Feb. 1978, Cushman Brook, active state; b. 15 Feb. 1978, Cushman Brook, commencement of resorption.

winter gametes are could explain whether spring or summer spawning had occurred. The small size of the free ova, in particular, in relation to summer eggs indicates that maturity probably was not complete at the inception of resorption.

Although it would be desirable to examine other populations of this and other species of the Margaritiferidae, some interesting correlations concerning reproductive periodicity can be made utilizing available data. It can be seen that some variability exists in the dates of egg deposition in margaritiferids (Fig. 3). Records given by Murphy (1942) and Meyers and Milleman (1977) supplemented by histological observations of gonads (Heard, 1970; van der Schalie, 1970) suggest that *M. falcata* might engage in two reproductive cycles, one in early spring and one in early summer. The advantages of dual reproduction are immediately seen. If suitable host fish are plentiful then mussels can double glochidial infection and thereby greatly enhance animal production. If *M. falcata* is involved in dual reproductive cycles and *M. margaritifera* was at one time, why then has *M. margaritifera* discontinued its spring-summer cycle? It has often been stated that for a

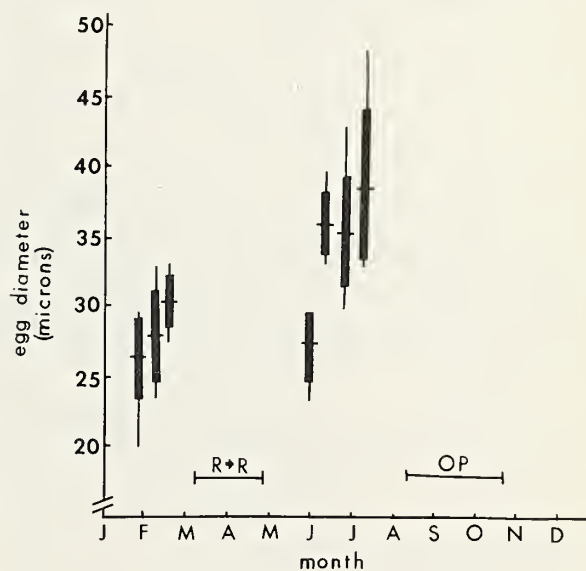


Figure 2. Observed annual ovarian cycle in studied populations. Diameters are of free eggs in gonad. R+R indicates resorption followed by recovery, OP designates oviposition. Divisions are mean, one standard deviation away from mean and range.

species living in a harsh environment, with high early life mortality, high productivity should be maintained to insure survival (Steams, 1976). Also, evidence indicates that the number of breeding cycles, in insects at least, during an entire reproductive (annual) period is genetically determined (Andrewartha and Birch, 1954).

A possible explanation involves the close interaction and feedback between mussels and host fish. Present day distributions of *M. margaritifera* in New England are limited to small streams with limited resources able to support a top predator such as the brook trout. Combined with habitat deterioration, i.e., increased water temperature, which would be increasingly unsuitable for brook trout, a decrease in numbers of available hosts develops. It might then be suggested that the numbers of glochidia produced over two cycles as compared to the numbers actually attaching to fish creates too high a ratio to remain an efficient cost-benefit trade off. Selection should then act to reduce and eliminate spring-summer reproduction thus allowing a shift of energy to growth and other life sustaining requirements.

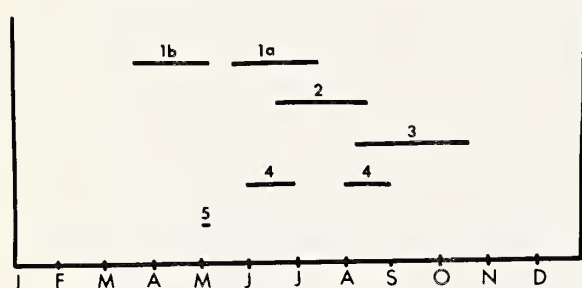


Figure 3. Periodicity of gravidness in the Margaritiferidae based on available studies. Numbers correlate species, observation of gravidness, and citation.

- | | |
|----------------------------|----------------------------|
| 1. <i>M. "falcata"</i> | a. Murphy, 1942 |
| | b. Meyers & Milleman, 1977 |
| 2. <i>M. margaritifera</i> | Harms, 1907, 1909; |
| | Ortmann, 1913; |
| | von Hessling, 1859 |
| 3. <i>M. margaritifera</i> | Smith, 1976 |
| 4. <i>M. margaritifera</i> | Conner, 1909 |
| 5. <i>C. monodonta</i> | Howard, 1915 |

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I should like to thank the following persons for their support and interest; Drs. Lawrence M. Bartlett, David J. Klingener, Drew M. Noden, William B. Nutting, and Herbert E. Potswald.

MINI-SYMPOSIUM: THE HOWS, WHYS, AND WHEREFORES OF BUILDING A SCIENTIFICALLY VALUABLE MOLLUSK COLLECTION

Moderator: Carol B. Stein

CURATORIAL TECHNIQUES FOR MARINE MOLLUSK COLLECTIONS

R. Tucker Abbott, Greenville, Delaware

SOME NEW IDEAS IN CURATING FRESHWATER MOLLUSKS

David H. Stansbery, The Ohio State University Museum of Zoology, Columbus, Ohio

THOUGHTS OF BUILDING A LAND SNAIL COLLECTION

W. Lloyd Pratt, University Museum, University of Nevada, Las Vegas, Nevada

WHAT WILL HAPPEN TO YOUR COLLECTION?

H. Wallace Roberts, Krusen Evans and Byrne, Philadelphia, Pennsylvania

ABSTRACTS OF PAPERS PRESENTED AT THE 1978 MEETING

ASPECTS OF REPRODUCTION IN *VILLOSA* (BIVALVIA: UNIONIDAE)

William H. Heard

Department of Biological Sciences
Florida State University, Tallahassee, FL.

Abstract

Sexual dimorphism, seasonal changes in marsupia, number of ovisacs and breeding seasons are

described for *Villosa amygdala*, *V. lienosa*, *V. vibex*, and *V. villosa* from Florida.

MORPHOLOGICAL AND EVOLUTIONARY RELATIONSHIPS IN *ALASMIDONTA* (UNIONIDAE)

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Abstract

Studies on the distribution, ecology and biometrics of *Alasmidonta* reveal significant interspecific relationships and apparent correlations with geological events. Some morphological trends in *Alas-*

midonta in particular and in Unionacea in general are discussed and the possible applicability of the diversity Maturation Hypothesis in that context is proposed.

REPRODUCTION OF THE FAMILIES UNIONIDAE AND AMBLEMIDAE

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Abstract

The triangular Unionidae glochidia are shed in mucus strings. They clamp on the exterior of fishes for their metamorphosis. The short-hinged Amble-

mididae glochidia are parasitic on the gills of fishes. Various bait structures are used to visually attract appropriate fish species.

CHARACTERISTICS OF THE GENUS *PERNA* (MYTILIDAE)

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Abstract

Marine mussels of the genus *Perna* (*P. perna*, *P. canaliculus* and *P. viridis*) are economically important along many warm coasts as a food resource by virtue of their nutritional value and rapid growth rates. The taxonomic status of the genus has been unclear for lack of unique and consistent criteria for

characterizing the genus. Many gross shell characteristics of mytilids are plastic and often of limited value in establishing valid relationships. Synonymies in the Mytilidae are numerous, the genus *Perna* notwithstanding; references in the modern literature to previously invalidated taxa (*Chlorornya* spp., *P. Pic-*

ta, *Mytilus smaragdinus* (syn. *P. viridis*)) are frequent.

Scanning electron microscopy of the hinge lines of *Perna* larvae and juveniles shows the development of typically mytilid hinge teeth accompanied by a broadening of the provinculum. In all three species of *Perna*, a series of "lateral" hinge teeth develop beyond the provinculum on both valves immediately following metamorphosis. In time, hinge teeth are obliterated by newly secreted shell material, but as a post-metamorphosis juvenile character, the development of the "lateral" teeth is a unique and consistent criteria for distinguishing mussel spat of the genus *Perna*. As adults, these mussels have posterior byssal and pedal retractor muscles which, because they are distinctly separate, leave several clearly discontinuous muscle scars on the shell located immediately anterior to the posterior adductor muscle scar. The degree of separation in the adult retractor

muscle scar complex decreases in the series *Perna* (separate), *Choromytilus*, *Aulacomya*, *Mytilus* (continuous). Anterior adductor muscles do not occur in adults of the genus *Perna*.

The three species within the genus *Perna* may be distinguished by shell coloration and by ecophysiological requirements. *P. perna*, the brown mussel of South America and the African continent, ranges from light to dark brown with infrequent shades of green and maroon. *P. viridis* of the Indo-Pacific from the Persian Gulf to India, Singapore and the Philippines, is brown with bright green to blue-green occurring along the posterior margins of the shell. *P. canaliculus* from New Zealand is green to brown frequently with indistinct darker zig-zag markings. *P. canaliculus* is found in cooler waters than *P. perna* or *P. viridis* while *P. viridis* thrives at lower salinities (28 ppt) than does *P. perna* (34 ppt).

A RECONNAISSANCE OF WEST AMERICAN LITTORINIDAE

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Abstract

Two dozen species and subspecies of Littorinidae are distributed through five life zones extending from the Arctic province through Aleutian, Oregonian and Panamic provinces to the Peru-Chile province of western South America. These provinces collectively may be termed the eastern Pacific. 1. *Littorina squalida* inhabits the Arctic province; 2a. *Littorina atkana* and *L. aleutica* the Aleutian province; b. *L. sitkana* spans both the Aleutian and a portion of the northern Oregonian provinces, 3. *L. scutulata*, *L. keenae* (formerly *L. planaxis*, see Nautilus 92(3): 123), and *L. newcombiana* the Oregonian province (along with the introduced *L. littorea* and *L. saxatilis*); 4a. *L. modesta*, *L. aspera*, *L. penicillata*, *L. pul-*

lata, *L. albicarinata*, *L. porcata*, and *Nodilittorina galapagensis* live on rocks in the tropical Panamic province; b. *L. zebra*, *L. varia*, *L. fasciata* and *L. scabra aberrans* live on shore vegetation, especially mangroves, in the same province; 5. *L. paytensis*, *L. peruviana*, *L. araucana*, and *L. fernandezensis* inhabit the Peru-Chile province. Recent field investigations by the author have made possible first hand observations on living species of the Oregonian and Panamic provinces. Collections at type-localities within these provinces have yielded fresh anatomical material for studies in progress on the classification and distributions of eastern Pacific Littorinidae.

FORMATION OF A POSTERODORSAL NOTCH IN LARVAL OYSTER SHELLS AND THE PRODISSOCONCH-I/II BOUNDARY IN THE BIVALVIA

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Abstract

In spite of the fact that the Prodissoconch-I/II boundary on larval shells of bivalves has been used as an important indicator of type of larval develop-

ment and capability of dispersal, there has never been a detailed explanation of how the boundary forms. Generally it is said to mark a change in mode

of calcification from that by the larval shell gland, which secretes prodissoconch-I, to that by the mantle edge, which secretes prodissoconch-II. Study of the morphology and mode of formation of an altogether different structure, a peculiar posterodorsal marginal deflection or notch and its growth track on larval shells of oysters, has led to a different explanation.

The marginal deflection, which is developed primarily in the left valve and to a lesser degree in the right, first appears at the prodissoconch-I/II boundary and disappears at metamorphosis, at the prodissoconch-II/dissoconch boundary. Scanning electron microscopy of anesthetized, critical-point dried veligers of *Ostrea edulis* L. demonstrates that the deflection is associated with a postanal ciliary tuft, which propels water out of the mantle cavity during prodissoconch stages but disappears at metamorphosis. The beating of these cilia deflects the labile mantle edge and its enveloping periostracum. Calcification then freezes the deflection to produce the notch and the trace which it leaves on the shell exterior during growth. Although the ciliary tuft is medial, the deflection is more prominent in the left valve than in the right because the pillbox-like interlocking of the valve margins produces a thinner edge on the left valve and mantle which is more easily deformed. The ciliary tuft can only produce the marginal deflection when the edges of the valve are

adjacent to it and nearly or completely closed.

This is a clear indication that the prodissoconch-I/II boundary marks that point in larval development at which the valves first come into contact with one another at their free margins and completely enclose the body. Other morphological features and events which first appear at the prodissoconch-I/II boundary support this explanation: (1) massive hinge teeth and pillbox-like valve edges, which prevent shear between closed or near closed valves; (2) prominent commarginal growth lines, which are possibly formed by differences in rate of calcification associated with valve closure; (3) injuries affecting both valve margins at the same point, which indicate that valve margins closed on the same foreign object or were injured simultaneously after being closed; (4) regular geometric spiral coiling, marking a balance between marginal growth of the shell and volumetric size increase of the enclosed body; and (5) in species that brood their young, release from the parent, which is also the time when valve closure is first required for survival. Lastly, the actual transition from calcification by the shell gland (defined as the calcifying invagination of the ectoderm beginning in the gastrula stage) to that by the mantle edge is actually indicated by a change in shell ultrastructure on the umbo of prodissoconch-I and is therefore earlier than the prodissoconch-I/II boundary.

THE CAECIDAE OF BRAZIL

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Abstract

Caecidae were unknown from the coast of Brazil until the Marquis de Folin began his study of the family in 1867. The first western Atlantic caecids had been described by Stimpson in 1851, followed shortly after by Carpenter in 1858. Between them, these two authors described 12 species from the United States and Antilles. Folin published much more extensively on the family, and described 64 species and 27 varieties from the western Atlantic. Sixteen of these had Brazil as the type locality. These were all named over an eight year period, 1867-1874.

Shortly thereafter, in 1875, Dunker described *Caecum corneum* from Brazil. There was then a

long hiatus until Morretes cataloged the Mollusca of Brazil in 1949. Five years later, Morretes described *C. berthae*. The work of cataloging marine molluscs of Brazil has been carried on by E.C. Rios. His 1970 catalog listed six species of Caecidae, the 1975 catalog his sixteen. The true number seems to be somewhat larger than this.

This present work had its roots in a series of visits to the Laboratoire de Malacologie, Museum National d'Histoire Naturelle, Paris, from 1963 to 1973. There the types of the de Folin collection were examined. A small amount of material was sent to the writer by Ernst Marcus, and later several species were sent in by E.C. Rios. Edward Petuch then took

part in a small expedition to the Abrolhos Reefs of Brazil in the summer of 1977. He brought back a single bottom sample from the foot (21m) of one steep sided patch reef which contained over 350 specimens of eleven species of Caecidae. Many of the specimens are immature, a few are bored, and many are broken, indicating considerable predation. A considerable number are, however, adults in good

condition.

Folin described or reported 21 species from Brazil. Some are synonymous, and at least one species is very doubtful. There are probably 13 valid species described by Folin living along the coast of Brazil. Three more were described by Stimpson and Carpenter. And at least three species seem to be undescribed.

A REVISION OF THE LAMPSILIS ORBICULATA (HILDRETH, 1828) COMPLEX (MOLLUSCA: BIVALVIA: UNIONACEA)

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Abstract

Members of the *Lampsilis orbiculata* (Hildreth, 1828) complex have been found living in at least seven somewhat isolated river systems within the Mississippi River basin of North America. A compari-

son of the anatomy of both the shells and the soft parts of available material reveals the presence of several distinct taxa within this complex.

MULTIVARIATE ANALYSIS OF STRUCTURE IN A FRESHWATER GASTROPOD COMMUNITY: PRELIMINARY RESULTS

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Abstract

If each species of a community must maintain some minimum niche hypervolume, high overlaps between species along one resource axis should necessitate lesser overlaps between the same species along others. To test this hypothesis, habitat and functional overlaps between sympatric snail species pairs were estimated using multivariate analysis, and the relationship between the two overlaps was examined. The community investigated included 29 snail species collected in 162 quantitative samples of plants and macrobenthos made by F.C. Baker at Oneida Lake, New York, in 1917.

I used multiple discriminant analysis to maximize the resolution among the habitats of 6 Oneida Lake snail species on the basis of 23 environmental variables. The magnitude of pairwise habitat overlap was estimated using the F statistic testing equality of

species means. As similar morphology is generally considered indication that species have similar functions within a community, I measured 11 shell and radula characters for at least 5 individuals of each species. The morphological similarity among the 6 species was measured as the euclidean distance between points in a principal component analysis. Then habitat overlap was regressed against morphological similarity (functional overlap) using the least squares method. The slope of the regression line was indeed negative, though different from 0 only at the .1 confidence level. So it is suggested that, as 2 species become more distinct in function within a community, they tend to occupy more distinct habitats. Work continues on the remaining 23 species, and numerous alternate methods of data treatment remain to be explored.

THE URETER-MANTLE RELATIONSHIP IN *SUCCINEA OVALIS*

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Abstract

In a routine survey of pneumostome-related structures of the mantle edge of a variety of terrestrial pulmonates, departures from the expected pattern of termination of the ureter were noted in specimens of the heterurethran *Succinea ovalis*. In the usual pattern the ureter opens by a slender duct in the left wall of the channel which leads to the pneumostome. The ureteric pore is located directly across this channel from the opening of the hindgut. Observed departures from this pattern include the blind termination of the ureter after a convoluted course

close to the leading edge of the mantle, connection with the hindgut within the region of the thickened mantle edge, and connection with the hindgut before it reaches the mantle edge. In all cases there are extensive regions in which the ureter is in intimate association with the blood channels and with the delicate lining of the mantle cavity; thus, there is a morphological basis for interchange of materials between fluid in the ureter, blood, and the air and fluid of the mantle cavity.

DEVELOPMENT AND FEEDING IN THE LARVAE OF TWO SPECIES OF AEOLID NUDIBRANCHS, *HERMISSENDA CRASSICORNIS* AND *AEOLIDIA PAPILLOSA*

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Abstract

The purpose of this study was to compare the early embryology, larval development, veliger morphology, and larval feeding behavior of two aeolid nudibranchs, *Hermisenda crassicornis* and *Aeolidia papillosa*.

Early embryology and larval development to hatching occurs similarly for both *Hermisenda crassicornis* and *Aeolidia papillosa*. Cleavage follows the typical spiral pattern of the Mollusca and results in the formation of a stereoblastula. Gastrulation occurs by epiboly and invagination, and is characterized by the formation of a sagittal cleft. The transitory trochophore is rapidly succeeded by an early veliger larva. Subsequent maturation and increased activity within the egg capsule lead to hatching of free swimming veliger larvae seven and eight days after fertilization for *H. crassicornis* and *A. papillosa*, respectively.

At hatching both species are dextrally organized and exhibit planktotrophic morphology. Larval shells of both species are coiled and characterized by six to seven oblique striations on the ventral whorl. However, mean shell length of *Aeolidia papillosa*

larvae is significantly greater than the mean shell length of *Hermisenda crassicornis* larvae (116 and 140 μ m, respectively).

At hatching both species of larvae show polymorphism with respect to shell length, relative yolk reserves and feeding ability. Frequency distributions of shell-length are bimodal for both species. In each case, shell-length distributions were truncated with respect to the presence or absence of yolk reserves. The resulting distributions are normal. The mean shell length of non-yolky larvae (i.e. those larvae which were without yolk reserves and could feed on suspended phytoplankton) is significantly greater than the mean shell length of yolky larvae (i.e. those larvae which contained yolk reserves and could not feed on suspended phytoplankton). Finally, the mean shell-length of non-yolky (feeding) larvae increases as the size of available food particles is increased. For instance, shell-length of larvae feeding on *Pavlova lutheri* is significantly less than shell length of larvae feeding on a larger alga *Phaeodactylum tricornutum*.

BIOGEOGRAPHIC PATTERNS OF LAND SNAILS, PENNSYLVANIAN TO PRESENT

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Abstract

Revision of the Paleozoic land snails has led to an analysis of the patterns of stability shown by the older land snail families, in which 70.3% of the

Eocene or older family units show evidence of little distributional change since their first appearance in the fossil record.

A PHENETIC CLASSIFICATION OF THE LAND SNAIL FAMILY POLYGYRIDAE

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Abstract

A new classification based upon phenetic analysis of 35 conchological, anatomical, and behavioral characters is presented as a preliminary approximation to a natural classification. The classification sup-

ports the accepted higher level classification, while largely substantiating recent innovations at the generic and subgeneric level.

A SURVEY OF THE BIVALVE MOLLUSKS OF THE BUTTAHATCHIE RIVER,
ALABAMA AND MISSISSIPPI

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Abstract

The Buttahatchie River, a main tributary of the Tombigbee River, is one of the recruitment areas for the many freshwater mussel species inhabiting the Tombigbee. No previous Buttahatchie River mussel survey has been recorded, and few collections have

been made from it. We made collections along its lower 70 miles from Henson Springs, Alabama, to its mouth near Columbus, Mississippi. *Corbicula* and at least 40 mussel species inhabit this stretch.

THE MOLLUSCA OF THE CEDAR BOG NATURE SANCTUARY, CHAMPAIGN COUNTY, OHIO

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Abstract

Cedar Bog Nature Sanctuary is a unique assemblage of vegetation communities brought together by special geologic and hydrologic conditions. The effects of habitat stability, habitat uniformity, avail-

able cover, and moisture conditions in determining the distribution of the Mollusca of this sanctuary are discussed.

UNUSUAL SOUTH AFRICAN SLUGS

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Abstract

A group of slugs which resemble lepidopteran pupae were found on a recent South African trip.

They appear to be unknown and may be new to science.

FILTRATION DYNAMICS IN THE SPHAERIID CLAM,
MUSCULIUM PARTUMEIUM (SAY)¹

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Abstract

Seasonal filtration rates of the sphaeriid clam *Musculium partumeium* (Say) are determined from its ability to clear dilute suspensions of 2.020 micron polyvinyltoluene (PVT) beads. Adult members of the population can be described in terms of the expression: Filtration = kW^b , where W equals dry tissue weight, and k and b are constants. Juvenile clams under 1.8 mm in shell length (spat) are inactive until they begin to grow and must be treated separately. Adult animals display a dramatic increase in filtration rates corresponding with the spring and fall periods of peak growth and reproduction. Seasonal clearance rates for a representative 1.0 mg standard animal are 0.3, 2.1, 0.6, and 1.0 $\text{ml} \cdot \text{mg}^{-1} \cdot \text{hr}^{-1}$ for winter, spring, summer, and fall respectively. The coefficient b (defining the exponential relationship between filtration and dry weight) declines during the spring and fall activity peaks. Weight specific filtration is essentially uniform for all adults in the summer and winter ($b = 1$), but smaller

adults are proportionately more active in the spring and fall than are larger adults (b equals 0.45 and 0.66 respectively). Newly born spat are relatively inactive (filtration = $0.1 \text{ ml} \cdot \text{mg}^{-1} \cdot \text{hr}^{-1}$), but increase their filtration rate to that of small adults as they begin to grow. Clams are insensitive to temperature changes during most of the year ($Q_{10} = 1.0$), but exhibit a Q_{10} significantly greater than 1.0 during the winter months. *Musculium partumeium* is present in sufficient numbers to pump a substantial fraction of the total habitat volume each day (up to 30 and 10% of 89.5m^3 for the spring and fall respectively). The quantity of organic carbon suspended in the pond is nevertheless insufficient to meet the energy needs of the animals. This strongly suggests that deposit feeding is an important supplemental strategy.

¹Supported by grants from the University of Dayton Research Council and The Ohio Biological Survey.

GENETIC AND MORPHOLOGICAL VARIATION IN THE FINGERNAIL CLAM
SPHAERIUM STRIATINUM (LAMARCK)

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Abstract

Morphological and genetic variation was studied in 12 populations of *Sphaerium striatinum* from two drainage systems in southwest Ohio. Genetic variation was examined utilizing the techniques of horizontal starch gel electrophoresis. Morphological vari-

ation was based on shell dimensions (length, width and height). Stepwise discriminant analysis was used to determine which shell parameters were most important in discriminating between populations. These parameters were employed in determining

morphological distance (measured as the Mahalanobis distance) between populations.

At least 20 individuals were electrophoretically examined from each population. Variation was analyzed for 13 protein systems encoded by 27 genetic loci. Mean percent heterozygosity per individual was extremely low ($0 - 0.64\%$), while the percentage of polymorphic loci population ($3.7 - 18.52\%$), although low, was within the range for other invertebrates which have been examined with similar techniques. As indicated by standard genetic distances, there appeared to be no significant associations of populations within drainage systems. However, the small magnitude of the genetic distance (< 0.103) indicates that all populations examined are genetic-

ally similar. The 12 populations have 17 monomorphic loci in common, however, in different populations. The existence of a heterozygote deficiency in all populations may indicate that there is a high degree of self-fertilization and/or that there is selection against heterozygotes at an early embryonic stage.

No significant correlation was found between morphological distance and standard genetic distance ($r = 0.002$). This may indicate that, intraspecifically, there is a large environmental component in the determination of shell morphology. Preliminary data indicate that both the morphological and genetic techniques employed in this study are excellent means of distinguishing between species of *Sphaerium*.

RADULAR VARIATION IN THE GENUS *BUSYCON*

Jerry Harasewych

Biochemical Systematics Laboratory

Delaware Museum of Natural History, Greenville, Delaware 19807

Abstract

Radulae of for species of *Busycon* (twelve populations) were examined and variation in each character was analyzed. Variation in three characters was found to correlate well with animal size. One charac-

ter (number of cusps per rachidian) was invariant in the subgenus *Busycotypus*, but appears to be controlled by a single diallelic gene in the subgenus *Busycon*.

THE SPECIFIC DISTINCTIONS OF *LAMPSILIS ANODONTOIDES* LEA AND *LAMPSILIS TERES* RAFINESQUE

J.P.E. Morrison

United States National Museum of Natural History

Washington, D.C. 20506

Abstract

These two related species live in different habitats, even in the same river. *L. anodontoides* is higher, yellowish, and lives in sandy bottoms. *L. teres* is

more cylindrical, usually rayed, and lives in shallower muddy bottoms. The glochidia of *L. teres* are recorded as larger than those of *L. anodontoides*.

THE RELATIONSHIP OF *TULOTOMA* TO OTHER NORTH AMERICAN VIVIPARID GASTROPODS

Virginia A. Vail

Tall Timbers Research Station

Tallahassee, FL 32303

Abstract

The anatomical organization of *Tulotoma angulata* is compared to that in *Viviparus georgianus*, *Campeloma geniculum*, and *Lioplax pilsbryi*. Fur-

ther support of the current subfamilial classification is offered.

REMARKABLE ECOLOGICAL ADAPTATIONS OF THE SNAIL GENUS *TOMICHIA*, A GONDWANALAND RELICT OF SOUTH AFRICA

George M. Davis

Department of Malacology, Academy of Natural Sciences
Philadelphia, PA 19103

Abstract

Tomichia (Prosobranchia: Rissoacea: Pomatiopsidae) is most closely related to *Coxiella* of Australia and so-called *Oncomelania* of Brazil. With the breakup of Gondwanaland, South Africa has experienced climatic changes leading to increasingly arid

conditions. The *Tomichia* radiation of four species in Cape Province and Namaqualand is explored. *Tomichia ventricosa*'s ability to withstand salinity changes from 4 to 80 ‰ is discussed.

SCAVENGER LAND SNAILS

Joseph Vagvolgyi and Ronald Kipp

Biology Department, College of Staten Island
Staten Island, N.Y. 10301

Abstract

Various land snails from the Galapagos Islands and the eastern United States feed on carcasses of terrestrial arthropods. The amounts consumed may

be considerable in proportion to the snails' body weight. Carrion eating appears to be a common habit among terrestrial pulmonates.

THE EFFECT OF A NUCLEAR POWER PLANT EFFLUENT ON POPULATIONS OF SHIPWORMS AND OTHER INVERTEBRATES, 1974-1978

K. Elaine Hoagland

Department of Biology, Lehigh University
Bethlehem, PA 18015

Abstract

The warm water effluent from Oyster Creek Nuclear Generating Station has caused an outbreak of shipworms in the immediate area. Two subtropical species of shipworms are now found in Barnegat Bay near the station. I report the status of the ship-

worms outbreak since steps were taken to reduce it in 1974-1975. I discuss the impact the generating station has had on breeding and colonization by shipworms and mollusks belonging to the fouling community.

SOME BRAZILIAN ENDEMIC MARINE GASTROPODS

E.C. Rios

Museu Oceanografico
Rio Grande, RS, Brasil

Abstract

In this paper, I present a list of endemic marine gastropods of Brazil. The range, principal records,

habitat, and some synonyms are included.

MOLLUSKS OF FORT MACON, NC: 1860-1887 AND PRESENT

Hugh J. Porter

University of North Carolina Institute of Marine Sciences
Morehead City, NC 28557

Abstract

Fort Macon was the first area in North Carolina to have its molluscan fauna described in detail. A comparison of the present molluscan fauna with descrip-

tions of that of approximately 100 years earlier suggests that, with minor exceptions, its fauna has changed little in the intervening period.

THE MOLLUSCA OF LAKE WACCAMAW IN NORTH CAROLINA

David H. Stansbery and William J. Clench

The Ohio State University Museum of Zoology
Columbus, OH 43210

Abstract

Collections made at a series of fifteen selected sites on this coastal plain lake from 1963 to 1976 reveal an aquatic mollusk fauna containing at least

three species of gastropods and ten species of naiades. Several of these species appear to be found only in Lake Waccamaw.

POPULAR NAMES OF MOLLUSKS

R. Tucker Abbott

P.O. Box 4208, Greenville, DE 19807

Abstract

The use of vernacular or common names of shells preceded the development of scientific nomenclature, and has continued in the last 200 years throughout malacological literature and world lan-

guages. Local and national vernacular names, when properly identified, serve a useful purpose in fisheries, conservation studies, and conchology.

COMPARATIVE LIFE HISTORIES OF TWO POPULATIONS OF THE SPHAERIID CLAM, *MUSCULIUM PARTUMEIUM* (SAY)¹

C.M. Way, Daniel J. Hombach² and Albert J. Burky

Department of Biology, University of Dayton
Dayton, OH 45469

Abstract

The life history of *Musculium partumeium* was studied in a permanent pond and in an ephemeral pond in southwest Ohio. Population samples were taken monthly. The clams were collected from the pond substrate, washed in 0.5 mm sieves and fixed in neutral formalin. Shell lengths were measured to the nearest 0.2 mm. Measured samples were separated according to generation by examination of time series of sizer frequency distributions.

The ephemeral pond provides a harsh habitat due to its drying from early July through December. One

generation per year is normal for the population. Young are born in May-July just before the drying of the pond and remain "dormant" until the pond refills. Growth begins in January-March and continues until the adults die with the drying of the pond. The maximum life span is 13-15 months where adults may reach a maximum shell length of 10.1 mm.

Two generations per year are normal for the permanent pond with the major recruitment of two overwintering generations: one in the spring and

one in the fall. The maximum life span for both generations is 13 months where adults may reach a maximum shell length of 9.5 mm. In this permanent pond the newborn clams remain "dormant" over the summer months as if the xeric conditions of an ephemeral pond exist.

These data support the contention that *M. partumeium* evolved in an ephemeral habitat. The patterns of growth and reproduction for the spring generation in the permanent pond is essentially equivalent to the only growth and reproductive period in the ephemeral pond. It is possible that *M. partumeium* is genetically programmed for life in the ephem-

eral habitat. However, there is enough phenotypic plasticity to exploit favorable conditions for growth and reproduction in the permanent pond during the fall and in the ephemeral habitat in the odd year when the pond remains full or refills early in the fall.

¹Supported by grants from The University of Dayton Research Council and The Ohio Biological Survey.

²Present address: Department of Zoology, Miami University, Oxford, Ohio 45056.

A STUDY OF THE RELATIONSHIP OF *ELLIPTIO HOPETONENSIS* (LEA, 1838) AND *ELLIPTIO DARIENSIS* (LEA, 1842)

Frank L. Kokai

The Ohio State University Museum of Zoology
Columbus, OH 43210

Abstract

Shell characters of specimens of *Elliptio hopetonensis* (Lea, 1838) and *E. dariensis* (Lea, 1842) appear to link these two forms. Some characteristics of

the soft anatomy are unexpectedly diverse. Specimens having the same shell morphology may have distinctly different soft anatomy.

CHITONS COLLECTED BY THE AMERIPAGOS EXPEDITION TO THE GALAPAGOS ISLANDS

William Old, Jr.

The American Museum of Natural History
New York, NY 10024

Abstract

Twelve species of chitons are known to occur in the Galapagos Islands. Of these, examples of nine species were collected by the Ameripagos Expedition in 1971. All except one species, which is also reported from the Hawaiian Islands, are restricted in

distribution to eastern Pacific waters are largely confined to the Panamic faunal province. Fifty per cent of the species are apparently endemic to the Galapagos Archipelago.

A COMPARATIVE STUDY OF TWO SYMPATRIC, CLOSELY RELATED *OREOHELIX* SPECIES OF THE *O. HEMPHILLI* GROUP

W.L. Pratt

University Museum, University of Nevada
Las Vegas, NV 89154

Abstract

Oreohelix handi Pilsbry and Ferriss and *O. jaegeri* Berry occur as sympatric endemics in the Spring Range of Clark County, Nevada. A study of anatomical, conchological, and habitat characteristics was

undertaken to estimate the importance of these characters in species separation in this characteristic Great Basin group.

MOCKING BIRDS AND NORWAY RATS: PRINCIPAL PREDATORS
OF GALAPAGOS LAND SNAILS

Joseph Vagvolgyi

Biology Department, College of Staten Island
Staten Island, NY 10301

Abstract

Mocking birds and the introduced Norway rats consume up to an estimated 40% of some Galapagos land snail populations. It is possible that the

introduced rat was responsible for the extinction of one species of land snail on the Galapagos. Centipedes and native rats are secondary predators.

THE MANTLE GLANDS OF *LYONSIA HYALINA* CONRAD (BIVALVIA: ANOMALODESMATA)
HISTOLOGY, ULTRASTRUCTURE, HISTOCHEMISTRY AND FUNCTION*

Robert S. Prezant

College of Marine Studies, University of Delaware
Lewes, DE 19958

Abstract

Small, deeply staining, multicellular glands have been found lining the mantle edge of the sand covered bivalve *Lyonsia hyalina*. These glands, which average 70 μ m in length and 30 μ m in diameter in a 10 mm long clam, occur in alignment with low radial striations of the periostracum deep within the periostracal groove. Pallial hemocoelic pressure allows the eversion of these glandular organs to a point just beyond the mantle edge. A thin retaining sheath of epithelium, derived from the middle mantle fold, encircles all but the dorsal tip of the gland and merges with it at the internal origin and along the external margin of the gland.

The glands are composed of three cell types of complex ultra-structures. Flask-shaped secretory and supportive cells alternate throughout the gland while a third, ovoid cell type borders the gland near the line of fusion between the gland proper and the surrounding sheath. The secretory cells possess large Golgi complexes and produce a sulfated acid mucopolysaccharide. The secretion is deposited over the periostracum which is covered with very short, truncated spines. These spines entangle the mucoid secretion and may aid in its' distribution over the periostracum. The mucus, in conjunction with

the spines, entangle sand grains which form a sediment coat over the bivalve. The mucus is produced in conjunction with the periostracum and both are deposited simultaneously. This indicates that the mantle glands may be localized generative zones involved in later shell secretion. Thus the cells of the mantle glands, which originally secrete a mucopolysaccharide, are changed both in morphology and physiology to next secrete the periostracum, next the prismatic shell layers and so on.

Many species of *Lyonsia* possess a sand cover over at least a portion of the periostracum. This extra coat may function as a stabilization mechanism in shifting sediments, a protective device for the thin shelled bivalves or as a camouflage mechanism, especially for the siphonal region. Interestingly, *L. hyalina* occurs in a relatively dense population in Nahant Bay, Massachusetts along with the similarly sand covered solitary tunicate *Bostrichobranchus pilularis*.

Histology, transmission electron microscopy and histochemistry carried out at: Marine Science Institute, Northeastern University, Nahant, Massachusetts 01908

THE DISTRIBUTION OF *EXTRACTRIX* (CANCELLARIIDAE)

Richard E. Petit

P.O. Box 30
North Myrtle Beach, SC 29582

TEMPORAL HETEROGENEITY OF CERTAIN BIVALVE LARVAE FROM
THE PISCATAQUA-GREAT BAY ESTUARY, NEW HAMPSHIRE

Donna D. Turgeon

Wallops Island Marine Science Consortium

Wallops Island, VA

Abstract

Larval densities of certain bivalves varied significantly over tidal cycles regardless of season or year. Dichotomous populations of intertidal adults existed in the system. Adult and larval distributions signifi-

cantly differed between the harbor and Great Bay. Lower estuarine larvae were maximal on flooding tide; upper estuarine were the reverse.

AMU ANNUAL REPORTS

AMU ANNUAL BUSINESS MEETING, JULY 20, 1978 – WILMINGTON, NORTH CAROLINA

President Carol B. Stein called the general business meeting of the Forty-Fourth Session of the American Malacological Union to order at 2 p.m. in the auditorium of King Hall, University of North Carolina at Wilmington, North Carolina, on Thursday, July 20, 1978.

Minutes from the 1977 general business meeting were printed in the 1977 *Bulletin*. A call for corrections, additions, or approval brought motions requesting corrections of two printer's errors.

A line was omitted from the proposed budget disbursements and reads as follows:

"Printing (except *Bulletin* and *Newsletters*) \$280.00"

A line was omitted from Resolution 1. This Resolution should read as follows:

"1. Resolution that the AMU go on record against selling the membership mailing list. The *Bulletin*, which contains a listing of members, may be offered for the subscription price of \$10.00."

With the above corrections, the 1977 minutes were approved.

Recording Secretary Constance E. Boone summarized the report from Corresponding Secretary Paul Jennewein. Summary approved. (Full report printed below.)

The Recording Secretary presented a summary of membership, noting a decrease, and other activities for the 1977 fiscal year. Summary approved. (Full report printed below.)

Treasurer Myra L. Taylor presented a summary of income and disbursements, especially noting that her report covered the fiscal year 1977. Summary approved. (Full report printed below.)

Dr. Harold Murray, chairman of the auditing committee, reported the books in perfect order, so noted by signatures of members of the auditing committee on the Treasurer's report. Report approved.

The Recording Secretary summarized the report from Publications Editor Dee Dundee. The 1977 *Bulletin* was printed at a cost of \$3,337.62, \$662.38 under budget. The 1977 Fall Newsletter was printed at a cost of \$302.27. The 1978 Spring Newsletter

mimeographed at the University of New Orleans by Editor Dundee and her secretary at a cost of \$137.87, a considerable savings. Summary report accepted.

A resolution brought from Council was adopted as follows: The Publications Editor is authorized to mimeograph the Newsletters to continue cost savings.

William E. Old Jr., budget chairman, presented the proposed budget for 1979 as follows:

INCOME	
Memberships	\$6,600.00
Sales	
HTCS	300.00
Rare & Endangered	50.00
Bulletin Back Issues	200.00
Teskey Index	75.00
Page Charges to Authors	1,000.00
Proceeds from meeting	200.00
Donations	50.00
Legal fund, contributions	0.00
Miscellaneous	20.00
TOTAL	\$8,495.00

DISBURSEMENTS	
Bulletin	\$4,800.00
Newsletters	500.00
Conservation committee	200.00
Membership committee	25.00
President's fund	50.00
California filing fee	5.00
Officers transportation to meeting	500.00
Legal defense	50.00
Postage (except <i>Bulletin</i> & <i>Newsletters</i>)	485.00
Printing (except <i>Bulletin</i> & <i>Newsletters</i>)	200.00
Office Supplies	50.00
Postal permit	40.00
Miscellaneous	150.00
Annual meeting expenses	150.00
<i>Nautilus</i> advertising	20.00

Advertising AMU	200.00
Membership WSM	7.50
Editor's Expense	200.00
TOTAL	\$7,632.50
NET GAIN	\$862.50

Treasurer	Myra L. Taylor	Three Year Term
Councillor-At-Large	Margaret Teskey and K. Elaine Hoagland	Two Year Terms

Budget does not include interest on savings of about \$200.00.

The budget was approved as presented.

The 1979 site for the annual meeting was announced as Corpus Christi, Texas, and AMU will host a joint session Aug. 5-11, 1979, with the Western Society of Malacologists. Headquarters will be La Quinta Royale motor inn.

Recommendations concerning the 1980 meeting site were brought from Council as follows:

Resolution to provide 30 days for Vice-President Clyde Roper to provide a site for the annual meeting in New England. If he does not select one, the meeting site at Louisville, Kentucky, will be accepted for 1980. (The Louisville Conchological Society has submitted an invitation for 1981 but would consider having the AMU meeting there in 1980). APPROVED.

Resolution that Dr. Clyde Roper inform the President of the decision at the end of 30 days and the President will inform all members of Council within 10 days of Dr. Roper's report to the President. APPROVED.

Dr. Stein presented the 1977-78 Conservation Committee report which is printed below in full. REPORT APPROVED.

Dr. Stein reported initial efforts to explore the need for common names for mollusks and read her letter to Dr. David Stansbery asking him to serve on a committee to report on the matter to Council at this 1978 meeting. This resulted in the following resolution brought from Council: "A committee should be established to prepare a list of common names of mollusks of medical importance, commercial importance, of major food supply, and selected mollusks as determined by the committee." APPROVED.

Dr. Ruth Turner, chairman of the nominating committee, reported the following candidates selected for offices to be filled at this meeting:

President	William E. Old Jr.	One Yr. Term
President-Elect	Dr. Clyde F.E. Roper	One Yr. Term
Vice-President	Dr. Richard S. Houbrock	One Yr. Term

Slate approved by acclamation.

William Old announced that AMU had sent an exhibit of shells and AMU publications to Italy for an international display. Emphasis on edible mollusks was stressed.

There was no report from the membership chairman for the year, but Council brought a resolution asking that the President immediately arrange suitable ads in several publications promoting AMU publications and membership as provided in the budget. APPROVED.

Resolutions brought from Council to elect as honorary life members of the American Malacological Union Dr. Harald Alfred Rehder and Dr. Joseph Paul Eldred Morrison were APPROVED.

The resolution from Council that AMU publications be sent to the Lisbon Museum to help rebuild the library destroyed recently by fire was approved.

Dr. Stein reported on the continuing development of the AMU Archives under Dr. William E. Clench's chairmanship. A resolution was brought from Council as follows: The AMU Archives housed at the Delaware Museum shall be moved to the Mollusk Department of the Academy of Natural Sciences of Philadelphia, PA. APPROVED.

A resolution was brought from Council that the President appoint a committee to establish the feasibility of offering an AMU trophy as an award at shell shows. This committee will report prior to the 1979 Executive Council meeting. APPROVED.

Several conservation actions were discussed at Council on review of recommendations from the general conservation meeting held on July 17 during this annual session. The following resolutions from Council were presented:

Resolution that AMU go on record opposing habitat destruction on the Tar River that endangers endemic mollusks. APPROVED.

Resolution that AMU go on record requesting that the government not fund projects that would exterminate or seriously jeopardize an endangered species. APPROVED.

Resolution that a letter be written to the Nature Conservancy recommending that land at Lake

Waccamaw be purchased. APPROVED.

Resolution to establish a basis for handling conservation matters through the establishment of an Executive Council Committee consisting of a chairman appointed by the President and two additional council members appointed by the President and two additional council members appointed by the new chairman and approved by the President. The chairman will follow the mandate to handle routine matters during the year and bring only matters to the annual meeting that need handling by Council. Conservation matters brought up at the annual meeting will be coordinated with the Executive Council on Conservation and the report to AMU Council will be made by the Chairman of the Executive Council on Conservation in as brief a form as possible, requesting action only on matters necessitating full deliberation of the AMU Council. APPROVED.

A resolution brought from Council was ADOPTED as follows: That AMU pay \$25.00 membership dues to the Association of Systematic Collectors so that AMU can be assured access to that national organization concerned with the development of collection resources and user community, and that the AMU Council of Systematic Malacologists continue to represent AMU.

A special concern about AMU membership and program updating resulted in some important resolutions brought from Council as follows:

Resolution that Dr. Alan Solem and Dr. George Davis and an amateur member of AMU they select work towards developing programs, in cooperation with the Vice-President, to interest and encourage amateur members. APPROVED.

Resolution that the AMU conference be advertised by the President in *Science* and other professional and educational journals four months in advance of the annual meeting. Professional highlights of national interest will be stressed. APPROVED.

Resolution that Mr. William Old prepare a symposium program of national importance to bring to AMU expert professionals within AMU and from outside AMU that would be advertised in the meeting notices in *Science* and other professional publications four months prior to the 1979 meeting. APPROVED.

Resolution that the Vice-President develop a symposium or alternative program, starting now,

that would have national prominence and bring to AMU expert professionals both within AMU and from outside of AMU. APPROVED.

Resolution that the Vice-President work in concert with the President-Elect to establish a prominent program with outreach to outstanding malacologists outside of AMU to encourage attendance at the AMU meetings and encourage them to bring their students to actively solicit members from the scientific community who are not AMU members. This motion is to establish long-range planning for AMU meetings to assure top level professional involvement thus stimulating student and professional participation. Such programs need development two years before the fact. APPROVED.

Resolution that Dr. Alan Solem and Dr. George Davis serve to aid the Vice-President to make the mechanism, as provided by the preceding resolutions, work. APPROVED.

A call for other new business brought a motion from Dr. George Davis, seconded by Dr. Louise Kraemer, requesting that the President appoint a three member committee to review the dues structure and finances of AMU and to make a report to the Executive Council in 1979. Provision for reassessment in blocks of five years at a time should be considered in recommendations to Council. APPROVED.

A motion by Dr. George Davis, seconded by Dr. Tucker Abbott, required the secretary to request the Editor of the AMU Bulletin to publish an errata statement recognizing Jerry Bijur as chairman of the host committee for the 1977 Naples AMU meeting. APPROVED.

Dr. Don Moore, seconded by Dr. Abbott, presented a motion asking that Mexican biologists be informed that they would be welcomed to the meeting in Corpus Christi in 1979. APPROVED.

Dr. Abbott, seconded by Dr. Moore, made the motion that telegrams of greetings from this session be sent to the honorary life president, honorary life members and a former long-time officer not present at this session. APPROVED.

A motion to adjourn at 2:55 p.m. was approved.

Respectfully submitted,
Constance E. Boone
Recording Secretary

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING DECEMBER 31, 1977

CHECK BOOK BALANCE, JANUARY 1, 1977

RECEIPTS:

Memberships: Regular	4747.00	
Life	154.33	
Sustaining	192.00	
Corresponding	203.28	
Clubs & Institutions	1410.00	
Subscriptions	81.50	6788.11
Sales: HOW TO STUDY & COLLECT SHELLS	360.13	
RARE & ENDANGERED SPECIES	92.25	
TESKEY INDEX	110.50	
BULLETIN, Back Issues	292.00	
Reprints	166.55	1021.43
Proceeds of Columbus Meeting, 1976	490.68	
Proceeds from 1976 Auction	935.53	
Page Charges To Authors	1110.00	
Donations — From Dues Notices	241.50	
Miscellaneous Receipts	24.25	
Transferred from Savings to Checking Account	1510.58	4312.54
Total Receipts From All Activities		12122.08
TOTAL CASH ACCOUNTED FOR:		<u>12122.08</u>
		<u>\$13947.28</u>

DISBURSEMENTS:

BULLETIN, Printing, Postage, Etc.	4533.76	
NEWSLETTERS, Printing, Postage, Etc.	671.07	
TESKEY INDEX, Printing, Postage, Etc.	1006.71	
Executive Council Conservation Committee	11.94	
Legal Expenses	55.80	
President's Expenses	22.43	
California Filing Fee	5.00	
Officers' Expenses To Meeting (3)	752.32	
Other Postage	350.09	
Other Printing	150.12	
Office Supplies	35.77	
Membership Dues, W.S.M.	5.00	
Miscellaneous Expenses	132.12	
Transfer of Funds/Life Membership to Cert. of Dep.	1000.00	
Transfer of Excess Funds to Savings	2500.00	11232.13
Total Disbursements From All Activities		<u>11232.13</u>

CHECK BOOK BALANCE ON DECEMBER 31, 1977

2715.15

TOTAL CASH ACCOUNTED FOR:

\$13947.28

1st. Federal Savings Acct. #2-6621

10.54

Interest added

.04

Total

10.58

1st. Federal Savings Acct. #112106	3845.30	
Interest added	<u>15.31</u>	
Total		<u>3860.61</u>
		<u>3871.19</u>
These two accounts closed. \$1,510.58 transferred to Checking Acct., & \$2,360.61 to San Antonio Savings Acct. #005-034514		
Savings Acct. #005-034514	2360.61	
Interest added	110.62	
Transfer to Checking Account	-1510.58	
Transfer from Checking to #005-034514	2500.00	
Transfer to San Antonio Savings Certificate #5-904812 for Life Membership Fund	<u>-1237.54</u>	
Total		2223.11
Certificate of Savings #5-904812, Life Membership Fund from #005-034514	1237.54	
Transfer from Checking Account	1000.00	
Interest Added	<u>37.07</u>	
Total		<u>22274.61</u>
TOTAL SAVINGS		4497.72

RECAPITULATION OF ASSETS, DECEMBER 31, 1977:

Cash in Checking Account, Mercantile Bank	\$2715.15
Treasurer's Petty Cash	25.00
Secretary's Petty Cash	125.00
San Antonio Savings Account #005-034514	<u>2223.11</u>
TOTAL ASSETS	5088.26
LIFE MEMBERSHIPS CERTIFICATE OF SAVINGS #5-904812	<u>2274.61</u>
A.M.U. NET WORTH, DECEMBER 31, 1977	2813.65
CHANGES IN CAPITAL ACCOUNT:	
A.M.U. CAPITAL ACCOUNT, JANUARY 1, 1977	3697.83
A.M.U. CAPITAL ACCOUNT, DECEMBER 31, 1977	<u>2813.65</u>
NET DECREASE IN ASSETS IN 1977	884.18

Respectfully submitted,
Myra L. Taylor
Treasurer

REPORT FROM THE RECORDING SECRETARY

Membership for the fiscal year 1977 was as follows:		Foreign	14
Honorary Life President	1	Clubs, regional org., business	45
Honorary Life Members	6	Life Members	<u>29</u>
Regular Members		Total	760
(All Western Hemisphere)	520	Suscriptions to Bulletin	6
Additional Family Members	95	The total figure for memberships in 1976 was 784. There were 5 subscriptions in 1976. Therefore, we show a decrease in memberships from all categories of 24 in 1977. We had nine formal resigna-	
Foreign Corresponding Members	13		
Affiliated Members (Institutions)			
Domestic	37		

tions and six deaths were reported. We completed two more life memberships and enrolled 65 new members. Eighty-nine members did not rejoin in 1977.

By July 1, 1978, we had enrolled 35 new members from all categories and had one new subscription. One death had been reported.

Since we continue to lose approximately ten percent of the membership each year, it is important that members encourage membership from new workers in the field of malacology. There has been no major push to secure members for two years.

New membership information and enrollment forms have been printed by the Recording Secretary in 1977. Council members received copies with the distribution of 1977 Executive Council minutes. These forms are being used by several officers to

encourage and secure new members. They are available to all members.

Expenses for this office in 1977 were \$203.40. Most of this was for postage to enroll new members, mail ordered Bulletins, *Endangered Species Symposium* and *How to Study and Collect Shells*. During the last four months of 1977 the bonus gifts of *American Malacologists* and the 1975 *Supplement* were also mailed new members.

We continue our efforts to keep addresses updated to avoid costly return mail. Approximately 15 returns per mailing are noted.

Transportation charges to AMU for attending the Naples meeting were \$200.00.

Respectfully submitted,
Constance E. Boone

REPORT FROM THE CORRESPONDING SECRETARY

The increase in postage apparently has discouraged letters from the curious wondering about what American Malacological Union members do and correspondence hasn't been the task it once was. Mail is still received by Mrs. Marian S. Hubbard, former corresponding secretary, and forwarded.

Since December, 52 books have been mailed out to persons, institutions and booksellers who have requested them. Total collected in that period has been \$99. During the last half of 1977, 25 books were mailed out for a total of \$53.05. (The odd amount results from postage charged the commercial accounts.) Museum shops and booksellers receive customary discounts.

A release on the North Carolina meeting was sent to about five publishers, with most of them apparently publishing them. However, only about three of the inquiries on the AMU meeting could be traced directly to the release.

The Wilmington Star-News has printed three articles on the meeting, so far, resulting from articles submitted.

Expenses and postage for the past half year have totaled \$72.73.

Respectfully submitted,

Paul R. Jennewein

CONSERVATION COMMITTEE AND EXECUTIVE COMMITTEE ON CONSERVATION 1977-78 REPORT

In the Big Darby Creek case, the Ohio Supreme Court overturned the ruling of the lower courts and upheld the constitutionality of Ohio's Scenic Rivers Act. The AMU, together with Rivers Unlimited, The Darby Creek Association, and The Ohio Environmental Council, had intervened in this case as Friends of the Court on behalf of the Ohio Department of Natural Resources, in defense of the Act. Now that the Director of Natural Resources has established his right to declare Big Darby Creek a State

Scenic River, AMU will urge him to do so to protect the four bivalve mollusk species on the official Ohio list of Endangered Wild Animals which are known to live in Big Darby Creek.

A copy of the 1976 AMU letter opposing further construction of the Cross Florida Barge Canal and urging restoration of the Oklawaha River to its natural state was sent, together with a cover letter, to Senator Mike Gravel, Chairman of the Subcommittee on Appropriations, U.S. Senate.

A letter was sent to the U.S. Army Corps of Engineers noting that many vanishing species of endemic freshwater mollusks still survive in the Duck River in Tennessee, and that these species would be adversely affected by the completion of the Columbia Dam. We recommended that the Corps deny the Tennessee Valley Authority's request for a permit to continue construction of this impoundment.

Another letter was sent to the Corps regarding a permit for proposed channel modifications in the Olentangy River at Columbus, Ohio. A copy of Dr.

Stein's paper from the 1972 AMU Bulletin was enclosed, and it was noted that *Quadrula cylindrica* and *Pleurobema clava*, both on Ohio's official list of Endangered Wild Animals, had been found in the area to be channelized. The corps was urged to actively seek alternatives which would not further endanger the river's native stream life.

Carol B. Stein, Chairman
Executive Committee on Conservation

THE AMERICAN MALACOLOGICAL UNION, INC. ACTIVE MEMBERS 1978

Membership List Revised October 15, 1978

Abbott, Dr. R. Tucker, P.O. Box 4208, Greenville, DE 19807.
Aguayo, Dr. Carlos G., Dept. of Biology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708.
Ahlstedt, Steven, 34 East Norris Rd., Norris, TN. 37828. (Biological Aide in Fisheries, TVA).
Alarcon, Benito F., Corroero, Isla de Pascua, Chile (Easter Island mollusks).
Albert, Mrs. Ernest, 905 S. Bayshore Blvd., Safety Harbor, FL. 33572.
Alexander, Robert C., 423 Warwick Rd., Wynnewood, PA. 19096.
Allen, James E., 1108 Southampton Dr., Alexandria, LA. 71301. (Tertiary miro-mollusca).
Allen, Dr. J. Frances, 7507 23rd Ave., Hyattsville, MD. 20783.
Allen, Mrs. Lawrence K., Box 822, Port Isabel, TX. 78578 (*Murex*, *Pecten*, world marines; dealer)
Allen, Miss Letha S., 187 Argyle St., Yarmouth, Nova Scotia, Canada B5A 3X2 (General).
Anders, Kirk W., Shells of the Sea, Inc., P.O. Box 1418, Ft. Lauderdale, FL. 33302 (*Volutidae*, all rare shells).
Anderson, Carleton Jay Jr., 56 Kettle Creek Rd., Weston, CT. 06883.
Andrews, Dr. Jean, 241 Melrose, Corpus Christi, TX. 78404.
Armington, Mr. and Mrs. Stewart F. Jr., 15932 Brewster Rd., Cleveland, OH. 44112 (*Cypraea* of Australia).
Ashwell, James R., 2125 Mohawk Trail, Maitland, FL. 32751 (General).
Athearn, Herbert D., Museum of Fluvial Mollusks, Rt. 5, Box 499, Cleveland, TN. 37311 (Freshwater mollusks).
Athearn, Mrs. Roy C., 5105 N. Main St., Fall River, MA. 02720. (Land shells)
Austin, Lyn Michele, 9401 Roberts Dr. 20-C, Atlanta, GA. 30338

Avellanet, Mrs. Helene, 105 Clipper Way, Fair Winds Villas, Nokomis, FL. 33555.
Avery, Mrs. Rada G., Box 2557, Harbor, OR. 97415 (West American mollusks; exchange)
Babrakzai, Mr. Noorullah and Dr. Sianoosh Sam Sam, Dept. General Biology, Univ. of Arizona, Tucson, AZ. 85721.
Baerreis, David A., Dept. of Anthropology, 5240 Social Science Bldg., Madison, WI. 53706. (Paleoecological interpretation through mollusks).
Bailey, Dr. Joshua L. Jr., 4435 Ampudia St., San Diego, CA. 92103.
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Baker, Sam, Candi, Jeffrey and Ryan, 1530 Astec Circle, Naperville, IL. 60540 (Collecting cones and cowries).
Barlow, Mrs. G. Barton, 76 Westervelt Ave., Tenafly, N.J. 07670.
Barr, John W. Jr., 16301 Buccaneer, Apt. 144, Houston, TX. 77062 (*Cypraeidae*).
Bates, Dr. John M., 1900 Dexter Ave., Ann Arbor, MI. 48103.
Bauer, Laura M., 2126 45th St., Galveston, TX. 77550 (All mollusks).
Baum, Newman N., 83 Weaving Lane, Wantagh L.I., N.Y. 11793.
Bazata, Kenneth R., Nalco Environmental Sciences, 4010 Northwest 39th St., Lincoln, NB. 68524. (Terrestrial pulmonates; *Dentalium*).
Bears, David T., 55 Bayberry Lane, E. Greenwich, RI. 02818 (Fisheries Biologist).
Beasley, Clark W., Dept. of Biology, McMurry College, Abilene, TX. 79605 (Terrestrial and freshwater mollusks).

- Beetle, Ms. Dorothy E., 1241 Kings Mountain Court, Columbus, GA. 31907 (U.S. Land and Fresh Water mollusks.)
- Bennett, Sally, 514 W. Rose Lane, Phoenix, AZ. 85013 (Panamic Province shells).
- Bequaert, Dr. Joseph C., 102 S. Sherwood Village Drive, Apt. 227, Tucson, AZ. 85710.
- Bereza, Daniel J. 825 N. 24th St., Philadelphia, PA. 19130 (Unionidae; Pleuroceridae).
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- Berry, Dr. and Mrs. Elmer G., 8506 Beech Tree Court, Bethesda, MD. 20034.
- Berry, Dr. S. Stillman, 1145 W. Highland Ave., Redlands, CA. 92373.
- Bianchi, Mrs. Ann, Box 235, Goodland, FL. 33933.
- Bickel, David, 1729 N. 5th St., Bismarck, N.D. 58501. (Systematics and ecology of freshwater mollusks, esp. Pleurocerids).
- Bijur, Jerome M., 135 Seventh Ave. N., Naples, FL. 33940 (Buy, exchange Florida, Caribbean and Gulf of Mexico marine).
- Bing, Ruth Rosser, P.O. Box 2612, Muhlenburg Station, Plainfield, NJ. 07060 (Art-Photography, oil painting).
- Bippus, Mr. and Mrs. Alvin C., 2743 Sagamore Rd., Toledo, OH. 43606 (Marine gastropods).
- Blaser, James, 1846 Laurel Lane, Amherst, OH. 44001 (Florida mollusks; Ohio freshwater mollusks).
- Bleakney, Dr. J. Sherman, Dept. of Biology, Acadia Univ., Wolfville, Nova Scotia, Canada BOP 1X0 Nudibranchs and sacoglossads; ecology, zoogeography, systematics).
- Bledsoe, William D., 352 Bon Hill Rd., Los Angeles, CA. 90049.
- Body, Ralph L., 2538 10th Ave. W., Seattle, WA. 98119.
- Bogan, Arthur E., Research Ass't. Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916.
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- Borror, Kathy Gail, OSU, Museum of Zoology, 1813 N. High St., Columbus, OH. 43210.
- Boss, Dr. Kenneth J., Museum of Comparative Zoology, Harvard Univ., Cambridge, MA. 02138.
- Bottimer, L.J., Rt. 1, Box 205, Tow, TX. 78672 (recent and fossil mollusks).
- Boy, Duane M/S 0949, Ecological Services Group, Texas Instruments Inc., Box 5621, Dallas, TX. 75222.
- Boyd, Dr. and Mrs. Eugene S., 6806 Gillis Rd., Victor, NY. 14564 (All aspects of Phylum Mollusca).
- Brandauer, Mrs. Nancy E. and Mr. Carl M., 1760 Sunset Blvd., Boulder, CO. 80302.
- Branson, Dr. Branley A., P.O. Box 50, Eastern Kentucky Univ. Richmond, KY. 40475.
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- Brean, Clark, 705 E. Sherman, Lebanon, OR. 97355 (Student, Cypraea).
- Bretsky, Sara S., 91 Upper Sheep Pasture Rd., East Setauket, NY. 11733 (Ecology and evolution of Bivalvia, Tertiary and Recent).
- Bricker, Mrs. Minnie, Miss Donna Bricker, R.D. 6, Box 476, Hanover, PA. 17331 (Conchs and Whelks.)
- Britton, Dr. Joseph C., Dept. of Biology, Texas Christian Univ., Ft. Worth, TX. 76129.
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- Brown, Drs. Harvey and Marjorie, 9455 S.W. 81st Ave., Miami, FL. 33156.
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- Brunson, Dr. Royal Bruce, 1522 34th St., Missoula, MT. 59801.
- Buchanan, Alan, Missouri Dept. of Conservation, Fish & Wildlife Research Ctr., 1110 College Ave., Columbia, MO. 65201 (Fisheries biologist).
- Buckley, George D., 164 Renfrew St., Arlington, MA. 02174.
- Buerk, Dr. Minerva S., Maybrook Chalet, 331 Penn Rd., Wyncnewood, PA. 19096 (Anatomy, histology).
- Buffet, Miss Sydney, 41 Stratford Ave., Pittsfield, MA. 01201.
- Bullis, Harvey R. Jr., P.O. Box 490409, Key Biscayne, FL. 33149.
- Burch, Mrs. Beatrice L., P.O. Box 309, Kailua, HI. 96934 (Dredging).
- Burch, Dr. John B., Museum of Zoology, University of Michigan, Ann Arbor, MI. 48104 (Land and fresh water mollusks).
- Burch, Mrs. John Q., 1300 Mayfield Rd., Apt. 61-L, Seal Beach, CA. 90740.
- Burger, Sybil B. 3700 Gen. Patch N.E., Albuquerque, NM 87111 (Gulf of Mexico; land snails).
- Burky, Dr. Albert J., Dept. of Biology, Univ. of Dayton, Dayton, OH. 45469.
- Campbell, Mrs. Minnie Lee and Donald C., 3895 DuPont Circle, Jacksonville, FL. 32205 (General).
- Cantera, Sr. Jaime Ricardo, Universidad del Valle, Dept. de Biología, A.A. 2188, Cali, Colombia (ecology, taxonomy).
- Capo, Thomas R., 59 Nickerson St., Falmouth, MA. 02540 (Benthic ecology).
- Cardeza, R. Adm. and Mrs. Carlos M., Dec. to Mar. 29, P.O. Box 6746, Houston, TX. 77005; April 1 to Nov. 30, 1718 Jewel Box Dr., Sanibel, FL. 33957 (Florida and Texas shells).
- Cardin, Charles, 4284 E. Viking Rd., Las Vegas, NV. 89121.
- Carlton, James T., Dept. of Geology, Univ. of California, Davis, CA. 95616 (Estuarine and brackish water mollusks).
- Carney, Dr. W. Patrick, Box 14, NAMRU-2 Taipei, APO San Francisco, CA. 96263.
- Carson, John, 221 Elm Ave., Morrisville, PA. 19067.
- Castagna, Michael, Va. Institute of Marine Science, Washa-preague, VA. 23480 (Pelecypod larval behavior).
- Cate, Mr. and Mrs. Crawford N., P.O. Drawer 710, Rancho Santa Fe, CA. 92067 (*Mitra*, *Cypraea*; no exchanges).
- Cetnar, Dr. and Mrs. Eugene J., 4379 Ramsgate Lane, W. Bloomfield, MI. 48013.
- Chace, Emery P., 24205 Eshelman Ave., Lomita, CA. 90717.
- Chadwick, Albert F., 2607 Turner Rd., Wilmington, DE. 19803 (Marine mollusks).
- Chamberlin, Ursula (Mrs. John) Mountain View Rd., Fishkill, NY. 12524 (Compiling collection N. Atl. marines).
- Chandler, Doris M., P.O. Box 621, Chatham, MA. 02633 (Cones, *Cypraea*).
- Chanley, Mr. and Mrs. Paul, Proyecto Hatchery, Fundacino Chile y Universidad del Norte, Casilla 117, Coquimbo, Chile. Permanent home address: 1321 San Sovina Terrace, Port St. Lucie, FL. 33452.
- Chichester, Lyle F., Dept. Biol. Sciences, Central Conn. State College, 31 Chamberlain St., New Britain, CT. 06052 (Ecology of terrestrial gastropods, biology of land slugs).
- Christensen, Carl C., 1612 Kamole St., Honolulu, HI. 96821.
- Christie, Dr. John D., Dept. of Pathology, Univ. of Texas Medical Branch, Galveston, TX. 77550.

- Chrosiecowski, Przemyslaw K., APTDO 125, Maracay, Venezuela 3KO (Planorbidae).
- Clarke, Dr. Arthur H., Dept. of Mollusks, USNM, Smithsonian, NHB-E 514, Washington, D.C. 20560.
- Clench, Dr. William J., 26 Rowena St., Dorchester, MA. 02124.
- Clover, Phillip W., P.O. Box 83, Glen Ellen, CA. 95442 (Rare Cypraea, Conus, Voluta, Murex, Marginella – Buy and exchange).
- Clymer, George M., 378 Quinell Ave., Lakeland, MN. 55043 (Unionidae).
- Coan, Dr. Eugene V., 891 San Jude Ave., Palo Alto, CA. 94306.
- Cohen, Anne C. (Mrs. Daniel M.), Division of Crustacea, NMNH, Smithsonian Institution, Washington, D.C. 20560 (*Loligini* dae; *Litiopa melanostoma*).
- Coleman, Dr. Richard W., Dept. of Biology, Prof. of Science and Head, Upper Iowa College, Fayette, IA. 52142 (Environmental interrelationships, plants-invertebrates).
- Compitello, Mrs. Juliette, 5630 Alta Vista Rd., Bethesda, MD. 20034.
- Conde, Vincent, McGill University (Redpath Museum), Montreal, Canada.
- Cook, Dr. Susan B., Dept. of Zoology, The Ohio State University, 1735 Neil Ave., Columbus, OH. 43210 (Behavioral ecology of tropical marine gastropods; behavioral ecology of freshwater gastropods).
- Cooper, Robert W., 5012 Pfeiffer Rd., Peoria, IL. 61607 (Florida marine; *Murex*, *Pecten*, *Spondylus*, SCUBA).
- Corgan, Dr. James X., Dept. of Geography and Geology, Austin Peay State Univ., Clarksville, TN. 37040 (Microscopic gastropods).
- Cornely, Guy, 53 rue Jean-Jaures Raizet, Abymes, Gaudaloupe, French West Indies.
- Cosman, Mr. and Mrs. Dieter, 7 Oak Hill Rd., Huntington, NY. 11743 (Marine tropical and subtropical Gastropoda and Bivalvia worldwide).
- Courtney, Charles M., director, MAMES, 990 N. Barfield Dr., Marco Island, FL. 33937 (Aquatic ecology/malacology).
- Craig, Katherine B., 24 Savoy St., Colonia, NJ. 07067 (Mollusks of N.E. Coast of U.S.).
- Craine, Mrs. Ruth A., P.O. Box 2001, Southern Pines, NC. 28387.
- Cramer, Frances L., 766 Obispo Ave., Long Beach, CA. 90804 (Ecology, conservation).
- Crissinger, William and Myrna May, 820 N. Court St., Crown Point, IN. 46307.
- Croft, Mrs. Thomas L., 9393 Ladue Rd., St. Louis, MO. 63124 (Marine; fossils).
- Cull, Mrs. Robert R., 7927 Chippewa Rd., Brecksville, OH. 44141.
- Cummings, Raymond W., 37 Lynacres Blvd., Fayetteville, NY. 13066 (West Indies shells, esp. Windward and Grenadine Is.).
- Cutler, Mr. and Mrs. Henry H., 105 Abbott Rd., Wellesley Hills, MA. 02181.
- Cvancara, Dr. Alan Milton, Dept. Geology, Univ. of N. Dakota, Grand Forks, ND. 58202 (Pleistocene and Holocene continental mollusks, early Tertiary continental and marine).
- D'Aiuto, Mrs. John, Rt. #2, Box 65-J, West Highway 44, Wildwood, FL. 32785.
- Danforth, Louis L., 2529 Terry Lane, Sarasota, FL. 33581.
- Daniels, Mrs. Kathleen K., Box 265 A, Rt. 1, Apollo, PA. 15613 (*Haliotis*, *Murex*, *Spondylus*, *Pectinidae*, *Conus*, *Cypraea*, in order listed).
- Daniels, Ronnie H., 5330 Patrick Henry Dr., Memphis, TN. 38134 (Marine: *Volutes*, *Murex*, *Cowries*).
- Darcy, George H., Univ. of Miami Sch. of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Davenport, Mrs. Lillian B., 802 Cape Ave., Box 81, Cape May Point, NJ. 08212 (Conchology, malacology, anything pertaining to the sea).
- Davis, Dr. Derek S., Nova Scotia Museum, 1747 Summer St., Halifax, NS, B3A, 2M3 Canada (Gastropod biology and taxonomy).
- Davis, Dr. George M. and Dr. Elaine Hoagland, Dept. of Malacology, ANSP, 19th and the Parkway, Philadelphia, PA. 19103 and Assistant Professor of Biology, Lehigh Univ., Bethlehem, PA. 18015.
- Davis, Dr. John D., 25 Old Homestead Rd., Westford, MA. 01886 (Ecology of marine bivalves).
- Deatrick, Paul A., 218 S.W. 32 Ave., Miami, FL. 33135 (*Strombus*, *Busysca*).
- de Graaff, Gerrit, 10915 S.W. 55 St., Miami, FL. 33165.
- DeLuca, Mrs. John A. and Ms. Gladys DeLuca, 61 Deborah Rd., Hanover, MA. 02339.
- Demond, Miss Joan, 202 Bicknell Ave., #8, Santa Monica, CA. 90405.
- Dennis, Ms. Sally, TVA Forestry, Fisheries, and Wildlife Develop., Norris, TN. 37828 (Freshwater mussels).
- Dexter, Miss Norma, 150 Barker Hill Dr., RFD 3, Guildford, CT. 06437 (*Cypraea*).
- Dexter, Dr. and Mrs. Ralph W., Dept. Biological Science, Kent State Univ., Kent, OH. 44242.
- Dietrich, Mr. and Mrs. Louis E., 308 Veri Dr., Pittsburgh, PA. 15220.
- Dillon, Robert T. Jr., Dept. of Biology, Leidy Laboratory G7, Univ. of Pennsylvania, Philadelphia, PA. 19104.
- Dixon, Mrs. Ruth S., 711 Parker St., Durham, NC. 27701 (Marine).
- Dolin, Eric, 107 Briar Brae Rd., Stamford, CN. 06903 (*Conus* *Cypraeidae*, *Strombus*, *Voluta*).
- Draper, Bertram C., 8511 Blierot, Los Angeles, CA. 90045 (Eastern Pacific minute mollusks and all Western U.S. marine).
- DuBar, Jules R. and Susan S., Lakeview Hgts., Morehead, KY. 40351 (Cenozoic and recent mollusks, ecology and paleoecology).
- Dugdale, H.K., P.O. Box 1392, Wilmington, DE. 19899 (Editor, Chambered Nautilus Newsletter).
- Dundee, Dr. Dolores S., Dept. of Biology, Univ. of New Orleans-Lakefront, New Orleans, La. 70122 (Land mollusks, freshwater mussels).
- Dvorak, Stanley J., 3856 W. 26th St., Chicago, IL. 60623 (Muriidae).
- Eakle, Christine E. Rackey, William A., 2308 Breton Dr., District Heights, MD. 20028 (Worldwide collecting).
- Eddison, Grace G., M.D., "Wildwood," Rt. 4, Carlisle, KY. 40311.
- Edwards, Lt. Col. Corinne E., USAF (Ret.), P.O. Box 330691, Coconut Grove, FL. 33133 (Chitons; self-collected).
- Edwards, D. Craig, Dept. of Zoology, Morrill Science Center, Univ. of Massachusetts, Amherst, MA. 01023 (Population ecology and behavior of marine benthic mollusks).
- Emerson, Dr. William K., American Museum of Natural History, Central Park West at 79th St., New York, NY. 10024.

- English, Rita C. and James F., 10300 Terrace Court, Parma, OH. 44130 (Fossils: Florida and Caribbean; ecology of mangrove areas).
- Erickson, Carl W., 4 Windsor Ave., Auburn, MA. 01501.
- Eubanks, Dr. Elizabeth R., 2162 E. Minton Dr., Tempe, AZ. 85282 (Florida marine shells).
- Evans, Roger, 1900 Camino de la Costa, Apt. 1, Redondo Beach, CA. 90277 (Diver; marine mollusks of Southern California).
- Evans, Miss Susan E., 244 Congress Ave., Lansdowne, PA. 19050 (*Conus*, *Cypraea*, *Murex*).
- Eversole, Dr. Arnold G., Dept. of Entomology and Economic Zoology, Clemson Univ., Clemson, SC. 29631. (Interpopulation variation and bioenergetics of molluscan populations.)
- Everson, Gene D., 1660 SW 27th Ave., Ft. Lauderdale, FL. 33312 (World-wide collection with emphasis on Florida, Caribbean and miniatures).
- Fackert, Miss Dorothy M., 2 Wilson Rd., Apt. 16B, Sussex, NJ. 07461.
- Fechtner, Frederick R., 2611 W. Fitch Ave., Chicago, IL. 60645.
- Feinberg, Harold S., Dept. of Fossil and Living Invertebrates, American Museum of Nat. Hist., Central Park West at 79th St., N.Y., NY. 10024 (Land and freshwater mollusks).
- Ferguson, Dr. and Mrs. John H., 226 Glandon Dr., Chapel Hill, NC. 27514.
- Fieberg, Mrs. Kleinie, 1430 Lake Ave., Wilmette, IL. 60091.
- Finlay, C. John, 116 Tanglewood Lane, Newark, DE. 19711 (Marine mollusks Western Atlantic and Caribbean).
- Foehrenbach, Jack, 91 Elm St., Islip Manor, NY. 11751 (Marine ecology).
- Fontanier, Charles E., P.O. Box 9325, Fort Worth, TX. 76107 (*Cypraeidae*, *Unionidae*; Scuba, Ecology).
- Foot, Miss Mary K., Apt. 418, 7201 Spencer Hwy., Pasadena, TX. 77505.
- Foster, Mr. and Mrs. Edward W., 30 Bamboo Dr., Naples, FL. 33940.
- Foster, Mrs. Fred H., 401 N. Justus St., Oxford, IN. 47971.
- Franzen, Dr. Dorothea, Illinois Wesleyan Univ., Bloomington, IL. 61701.
- Frye, Mark W., Dept. of Geology and Mineralogy, OSU, 125 S. Oval Mall, Columbus, OH. 43210 (Naiads, Micropaleontology with specialty in Ordovician micro-mollusks).
- Fuller, Samuel L.H. and Mrs. Mary L.B. Fuller, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (World Naiads, Unionacea and Mutelacea).
- Fullington, Richard W. and Kate E., 215 Bonnie Brae, Denton, TX. 76201 (Land and freshwater gastropods of North America; curator, Invertebrate zoology, Dallas Museum of Natural History).
- Gallindo, Lic. Ernesto Santos, Jorge Elliot #12, Colonia Polanco, Mexico, D.F. 5.
- Gardner, Mrs. Sandra M., 1755 Univ. Ave., Palo Alto, CA. 94301 (*Vermetidae*).
- Garrett, Herman Benton II, Dept. of Biological Sciences, Univ. of New Orleans, New Orleans, LA. 70122 (Taxonomy of fresh water and land gastropods of the U.S.).
- Geller, Mrs. Leonard, 336 DeMott Ave., Rockville Centre, NY. 11570.
- Germer, Mr. and Mrs. John R., 653 Braircliff Ave., Maywood, NJ. 06707 (Mr., Photography of shells; Mrs., *Pectens* and *Murex*, shells of E. and W. Atl.).
- Germon, Mrs. Raye N., 27 Rosemont Dr., Gaithersburg, MD. 20760 (*Muricidae*, *Volutidae*, Mesozoic and Paleozoic fossils (marine)).
- Gibbons, Ms. Mary C., RD 2, Box 28, Clay Rd., Lewes, DE. 19958 (Grad student at College of Marine Studies, U. of Delaware).
- Gilbert, Dr. William H. and Dr. Mary Ann Gilbert, Dept. Biology, Simpson College, Indianola, IO. 50125 (Marine and freshwater bivalves — ecology, behavior, systematics; *Tellina*, *Macoma*).
- Gill, Richard W., Rt. #4, Charleston, IL. 61920 (Riverine Pel-ecypoda).
- Gilmour, Dr. Thomas H.J., Dept. Biology, Univ. of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0 (Ansimoyarian bivalves).
- Girardi, Dr. Elizabeth-Louise, 707 Kent Rd., Kenilworth, IL. 60043.
- Glazebrook, Sandra R., 7760 Margerum Ave., #228, San Diego, CA. 92120.
- Goethel, Lt. Col. (Ret.) and Mrs. Louis N., 9402 Nona Kay Dr., San Antonio, TX. 78217 (*Cypraea* — buy and trade).
- Gold, Albert, 118 W. 227 St., Bronx, N.Y. 10463.
- Goldberg, Michael, 6927 Williams Dr., Tampa, FL. 33614.
- Goodfriend, Glenn A., Comm. on Evol. Biology, U. of Chicago, IL. 60637 (Molluscan ecology).
- Gordon, Mackenzie Jr., Paleontology and Stratigraphy Branch, U.S. Geological Survey, Smithsonian, Washington, D.C. 20560.
- Greenberg, Bayle, c/o Tidepool Gallery, 3907 W. 50th St., Edina, MN. 55424.
- Greenberg, Mrs. Janis, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greenberg, Mrs. Ruth, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Guckert, Richard H., 1757 Kimberly Dr., Marietta, GA. 30060 (Systematics of freshwater mussels; ecology; physiology of *Nassariidae*).
- Gudnason, Mrs. Harold, 105 Danefield Place, Moraga, CA. 94556.
- Gugler, Dr. Carl W., School of Life Sciences, U. of Neb., Lincoln, NB. 68588 (Terrestrial pulmonates).
- Gunter, Dr. Gordon, Gulf Coast Research Lab., Ocean Springs, MS. 39564 (*Ostreidae*).
- Gussman, David S., 1141 Laguna Ave., Apt. #3, Burlingame, CA. 94010. (Aquatic ecology, feeding dynamics of aquatic organisms).
- Haas, Dr. John W., Kino Community Hospital, Dept. of Psychiatry, 2800 E. Ajo Way, Tucson, AZ. 85713 (*Volutes*, *Pectens*, *Spondylus*).
- Hagge, Mrs. Daniel, 20 North Hill Rd., Wausaw, WI. 54401.
- Haigh, Ernest S. and Marilyn E. and son, David, 6533 Orange-wood Ave., Cypress, CA. 90630.
- Hall, Eleanor R., 1230 N.E. 88th St., Seattle, WA. 98115 (Marine gastropods, esp. worldwide *Cypraea*).
- Hall, Mrs. Warner L., 727 Queen's Rd., Charlotte, NC. 28207.
- Hamilton, Dr. Paul V., Assistant Professor, Biology, Univ. of W. Florida, Pensacola, FL. 32504 (Behavior and ecology of gastropods).
- Hamilton, Ms. Suzanne, 631 Blossom, Rockville, MD. 20850 (Freshwater gastropods).

- Hamilton, Mrs. William J. Jr., 615 Highland Rd., Ithaca, NY. 14850.
- Hand, Dr. Cadet H. Bodega Marine Lab, P.O. Box 247 Bodega Bay, CA. 94923.
- Hanley, John H., Branch of Paleontology and Stratigraphy, U.S. Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center, Denver, CO. 80225 (Paleontologist specializing in fossil nonmarine mollusks.)
- Harasewych, Jerry, Delaware Museum of Natural History, Box 3937, Greenville, DE. 19807.
- Hargreave, Dr. David, Ass't. Prof. Nat. Scs., College of Gen. Studies, Western Mich. Univ., 1104 Berkshire Dr., Kalamazoo, MI. 49007 (Collecting and photography).
- Harman, Dr. Willard N., State Univ. College at Oneonta, Oneonta, NY. 13825 (Fresh water mollusca).
- Harris, Don V. Jr., 4525 Glebe Rd. N., Arlington, VA. 22207.
- Harris, Mr. & Mrs. E. Milton, 3237 Carlisle Rd., Birmingham, AL. 35213.
- Harry, Dr. Harold W., 4612 Evergreen St., Bellaire, TX. 77401.
- Hartenshtein, Raymond H., Biologist, 965 Belvoir Rd., Norristown, PA. 19401 (Fresh water malacology).
- Hartman, Joseph H., Dept. Geology/Geophysics, Univ. of Minn., 108 Pillsbury Hall, Minneapolis, MN. 55455 (Cretaceous-Eocene F.W. moll. of W. US; Viviparidae).
- Haskell, Mrs. William, 529 Via Lido Soud, Newport Beach, CA. 92663.
- Haven, Dr. Dexter S., 336 Lafayette Rd., Yorktown, VA. 23690 (*Mercenaria mercenaria*, *Mya arenaria*, *Crassostrea virginica*).
- Havens, Miss Susan E., 21 Varnum Ave., Pawtucket, RI. 02860 (Student).
- Havlik, Mrs. Marian E., 1603 Mississippi St., LaCrosse, WI. 54601 (Naiads of Miss. River).
- Hedges, Arlene J., 404 North East St., Crown Point, IN. 46307.
- Helms, Don R., Aquatic biologist, RR #3, Box 63, Bellevue, IO. 52031 (Special interest in Mississippi River).
- Hendrickson, F. Scott DDS, 2967 Madison Ave., Granite City, IL. 62040.
- Herr, Marion and Frank, 7901 Dewitt Dr., RFD #3, Baldwinsville, NY. 13027.
- Hettick, Mrs. G. Riley, 933 Lynnwood Dr., Bartlesville, OK. 74003.
- Hickey, Ms. Mary T., 4415 Independence St., Rockville, MD. 20853 (Scallops).
- Hickman, Dr. Carole S., Dept. of Paleontology, Univ. of Calif., Berkeley, CA. 94720 (tertiary molluscan paleontology).
- Hickman, Mrs. Harriette L., 20 Wilkie Blvd., Mamora, NJ. 08223 (Worldwide *Epitonium*).
- Hickok, George H., 27 Whitney Circle, Windsor, CN. 06095 (amateur).
- Hicks, Mr. and Mrs. Edwin S., 1522 Palmwood Dr., Eau Gallie, FL. 32935 (Recent and fossil marine shells of Western Atlantic).
- Higbee, Mrs. Florence and Dr. Joan Higbee, 13 North Bedford St., Arlington, VA. 22201.
- Hill, Frederick C., 6225 4th St., Bloomsburg, PA. 17815.
- Hillman, Dr. Robert E., Battelle-Clapp Laboratories, Duxbury, MA. 02332 (Molluscan ecology and physiology).
- Hingle, Mrs. James L. Jr., 2610 St. Nick Dr., New Orleans, LA. 70114.
- Hobbs, Sue, P.O. Box 153, Cape May, NJ. 08204.
- Hohman, Betty Jean, 10 Ferris, Apt. 101, Highland Park, MI. 48203 (cones, Volutes, Murices).
- Holiman, Mr. and Mrs. Wayne, Box 246, Edinburgh, TX. 78539.
- Holle, Dr. Paul A., 131 Holman St., Shrewsbury, MA. 01545 (Salt marsh snails).
- Hollister, S.C., 5 Parkway Place, Ithaca, NY. 14850.
- Homan, Mrs. Jacqueline A., Rt. 5, Box 230, Harlingen, TX. 78550.
- Hopkins, Dr. Sewell H., Rt. 3, Box 232, Gloucester, VA. 23061.
- Hornbach, Daniel J., Dept. of Zoology, Miami Univ., Oxford, OH. 45056 (Sphaeriid bivalves).
- Houbrick, Dr. Richard S., Associate Curator of Mollusks, Dept. of Invertebrate Zoology, NMNH, Smithsonian Institution, Washington, DC. 20560 (Zoogeography, systematics, evolution).
- Hubbard, Mrs. Marian S., 3957 Marlow Court, Seaford, NY. 11783 (Littorinidae; all juvenile mollusks).
- Hubright, Leslie, 4026 35th St., Meridian, MS. 39301 (Land snails and Hydrobiidae of Eastern United States).
- Huldrum, Marye, Sundial Beach Club, Sanibel, FL. 33957.
- Hulswit, Mart, 680 West End Ave., New York, NY. 10025 (SCUBA).
- Hunkins, Mrs. Ruth E., 133 Brook to Bay, Englewood, FL. 33533 (Miniature shells: exchange).
- Hyett, Dr. and Mrs. Marvin R., 403 Silverhill Rd., Cherry Hill, NJ. 08002.
- Imlay, Dr. Marc J. and Alice, Fish Wildlife Service, Dept. of Int. Office of Endangered Species, 1612 K. St. N.W., Washington, DC. 20240.
- Ing, Mrs. Mary C. and Michael B., Bella Vista Hospital Box 1750, Mayaguez, Puerto Rico 00708 (Small and minute shells of W.I.)
- Ishikawa, Samuel, 551 Fifth Ave., New York, NY. 10017.
- Isom, Billy G., Rt. 2, Box 217, Amy Drive, Killen, AL. 35645.
- Jackson, Ralph W., Rt. #1, Box 229, Cambridge, MD. 21613 (Exchange land shells).
- Jacobson, Morris K., Oct. to April. 865 Capon St. S.E., Palm Bay, FL 32905; April to Oct. 455 Beach 139 St., Rockaway Beach, NY. 11694 (East Coast: land, freshwater and marine; West Indian land shells).
- Jacobson, Mrs. Ursula, 5618 E. Montecito, Phoenix, AZ. 85018 (Indo-Pacific, esp. cones and cowries; West Coast-Panama).
- James, Brian, 24 The Links Rd., Apt. 210, Willowdale, Ont., Canada.
- James, Mrs. Frederic, 850 West 42nd St., Kansas City, MO. 64112.
- Janowsky, Robert and Dorothy, 946 Ralph Ave., Brooklyn, NY. 11236 (*Cypraea*, *Murex*, Volutes).
- Jass, Ms. Joan, 1171 N. 44th St., Milwaukee, WI. 53208.
- Jenkinson, John J. and Carolyn, 189 W. Lakeview Ave., Columbus, OH. 43202.
- Jenner, Charles E., Dept. of Zoology, Univ. of N.C., Chapel Hill, N.C. 27514 (Biology of *Ilyanassa*, *Solemya*, and commensal bivalves).
- Jennwein, Paul R. and Virginia N., Box 394, Wrightsville Beach, NC. 28480 (Raising mollusks in aquaria; writing and illustrating articles on shell collecting).
- Jensen, Russell H., R.D. #1, Box 55, Chadds Ford, PA. 19317 (Mollusks of Bermuda).
- Joffe, Ms. Anne, 1163 Kittiwake Circle, Sanibel Is., FL. 33957.
- Johns, Veronica Parker, c/o Seashells Unlimited, Inc., 590 Third Ave., New York, NY. 10016.

- Johnson, Col. Harvey A. (Ret.) 3915 S.W. 109th St., Seattle, WA. 98146.
- Johnson, Mrs. Kenneth L., 3206 Sussex Rd., Raleigh, NC. 27607 (World marine).
- Johnson, Richard I., 124 Chestnut Hill Rd., Chestnut Hill, MA. 02167.
- Johnstone, Mrs. Adelaide B., 226 Wasp, Corpus Christi, TX. 78412.
- Johnstone, Mrs. Kathleen Yerger, 2209 River Forest Rd., Mobile, AL. 36605.
- Jokinen, Eileen (Romach), Biology Dept. Suffolk Univ., Boston, MA. 02114 (Freshwater gastropods).
- Jones, Mr. and Mrs. Archie L., 4370 S.W. 14 St., Miami, FL. 33134 (*Liguus*).
- Jones, Meredith L., Division of Invert. Zoology, USNM, Smithsonian Institution, Washington, DC. 20560.
- Jones, Richard H., 1432 Dorsh Rd., South Eclid, OH. 44121.
- Josey, Mrs. John S., 222 Devonwood Dr., St. Simons Is., GA. 31522 (Worldwide: self-collected, exchange; Japanese shells and fossils of GA. and FL.; professional artist, marine shells and marine paintings, teaches art at Brunswick Junior College).
- Kay, Dr. E. Alison, General Science Dept., Univ. of Hawaii, 2450 Campus Rd., Honolulu, HI. 96822 (Indo-Pacific marine mollusca: systematics and ecology).
- Keegan, Mrs. Barbara, 54 Franklin St., Franklin, NH. 03235.
- Keefer, Dr. James H., 30 Park Lane, Chagrin Falls, OH. 44022 (Marine, esp. micro Gastropods – Epitoniidae and Terebridae).
- Keen, Dr. A. Myra, 2241 Hanover St., Palo Alto, CA. 94306.
- Keferl, Dr. Eugene P., 2610 Oriole St., Brunswick, GA. 31520 (Terrestrial gastropods).
- Kellogg, Michael G., Moss Landing Marine Laboratories, P.O. Box 223, Moss Landing, CA. 95039.
- Kemper, Mrs. Hessie, 11854 Josse Dr., St. Louis, MO. 63128.
- Kennish, Michael J., Madison Ave. at Punch Bowl Rd., Morristown, NJ. 07960 (Shell microstructure in mollusks).
- King, Gary and Debba, Bldg. 2072, Apt. 198, Randolph AFB, TX. 78148.
- King, Lucia E., Heron Club, 434 Broad Ave. South, Naples, FL. 33940.
- Kline, Mrs. George F., 240 Makee Rd., Apt. 10-A, Honolulu, HI. 96815.
- Klinkey, Mrs. Martha, 1336 S. 14th St., St. Charles IL. 60174. (*Cypraea*, *Murex*, *Strombus*).
- Kohn, Dr. Alan J., Dept. Zoology, Univ. of Washington, Seattle, WA. 98195.
- Kokai, Frank L. 3472 Green Meadows St., Columbus, OH. 43207.
- Kondo, Dr. Yoshio, 809 A. Isenberg St., Honolulu, HI. 96826.
- Kotrla, M. Bowie, Dept. of Biology, Trinity Univ., 715 Stadium Dr., San Antonio, TX. 78284 (Parasites of snails).
- Kraemer, Dr. Louise Russert and Dr. William D., Dept. of Zoology, Univ. of Arkansas, Fayetteville, AK. 72701 (Freshwater lamellibranchs).
- Kraeuter, Dr. John N., Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Ecology, distribution and systematics of Scaphopoda; benthic infaunal of U.S. East Coast).
- Krauss, N.L.H., 2437 Parker Place, Honolulu, HI. 96822 (Carnivorous land snails; biology).
- Kuczynski, Mrs. Florence, 5562 2nd Ave. N., St. Petersburg, FL. 33710 (Collect, exchange, photograph all shells).
- Kurz, Richard M., 1575 N. 118 St., Wauwatosa, WI. 53226 (Specimen shells).
- Kuzirian, Dr. Alan M., Zool. Dept., Univ. of New Hampshire, Durham, NH. 03824 (Nudibranch biology).
- Laavy, T.L., Rt. 5, Maruca Dr., Greenville, SC. 29609.
- Lalli, Dr. Carol M., Marine Sciences Centre, McGill Univ., 3600 Univ. St., Montreal, Quebec, Canada H3A 2T8 (Pteropod molluscs).
- Lamberts, Dr. Austin, 1520 Leffingwell, N.E., Grand Rapids, MI. 49505 (Coral reefs and associated mollusks).
- Landye, James Jerry, 3465 N. Jamison, Flagstaff, AZ. 86001.
- Lane, Lewis B., 204 Ransom St., Fuquay-Varina, NC. 27526 (Land and marine).
- Lane, Dr. Roger L., Ashtabula Campus, Kent State Univ., Ashtabula, OH. 44004 (Morphology, Histology).
- Lange, W. Harry, Dept. of Entomology, Univ. of California Davis, CA. 95616.
- Langworth, Richard M. and Barbara F., 20 Hart Ave., Hopewell, N.J. 08525 (Cowries and volutes).
- LaRocque, Dr. Aurele, 102 W. Beaumont Rd., Columbus, OH. 43214.
- Laursen, Dr. Dan, 4901 East Eastland, Tucson, AZ. 85711 (Arctic Subarctic mollusks; Free living larvae of Caribbean and Gulf areas).
- Lee, Dr. Harry G., 709 Lomax St., Jacksonville, FL. 32204 (American mollusks; marine mollusks of the Indian Ocean).
- Lee, Pamela, 2146 Mt. Olympus Dr., Los Angeles, CA. 90046 (Marine).
- Lemire, Ross, 184 Grandview Ave., Thornhill, Ont., Canada L3T 1J1.
- Lencher, Mrs. Jennie R., 144 N. Dithridge St., Apt. 408, Pittsburgh, PA. 15213.
- Leonard, Dr. A. Byron, 562 Snow Hall, Univ. of Kansas, Lawrence, KS. 66045.
- Lerner, Martin, 64 Thompson Ave., Oceanside, NY. 11572 (Worldwide marine).
- Leslie, John, B-129 Birge Hall, Univ. of Wisconsin, Madison, WI. 53706 (*Haliotis*).
- Lewis, Harold, 138 S. Twentieth St., Philadelphia, PA. 19103.
- Lewis, Mrs. J. Kenneth, 9207-48th Ave., College Park, MD. 20740.
- Lewis, Dr. and Mrs. John R., 23 W. 551 Warrenville Rd., Lisle, IL. 60532.
- Lewis, Randall B., 210 Chandler Dr., Mundelein, IL. 60060.
- Lindberg, David R. Dept. of Invert. Zoology, Calif. Academy of Sciences, Golden Gate Park, San Francisco, CA. 94118.
- Linsley, Dr. Robert M., East Lake Rd., Hamilton, NY. 13346.
- Littleton, Thomas G., 511 Colonial Parkway, Devine, TX. 78016.
- Long, Dr. Glenn A., 608 Stevenson Lane, Towson, MD. 21204 (Ethnoconchology).
- Long, Steven J., 792 Laurie Ave., Santa Clara, CA. 95050 (Opisthobranchs, Nudibranchs, Cephalaspideans, Notaspideans, Lamellarians).
- Lopinot, A.C., 45 Northcrest, Litchfield, IL. 62056 (Aquatic biologist, taxonomy and life history of freshwater mussels).
- Lowry, Walter G. and Nelle H., 552 Old Lundy Rd., Macon, GA. 31204 (Western Atlantic).
- Lubinsky, Dr. Irene, 32 Thatcher Drive, Winnipeg, Man., Canada R3T 2L2 (Marine bivalves of the Canadian Arctic).

- Lutz, Richard A., Dept. of Geology and Geophysics, Yale Univ., New Haven, CN. 06520 (Bivalve shell structure and mineralogy; molluscan aquaculture; bivalve larval ecology).
- Lyons, Miss Sarah, 81 Lakeview Ave., N.E., Atlanta, GA. 30305.
- Lyons, William G., Florida Dept. of Natural Resources, Marine Lab, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Florida and West Indian mollusks).
- MacBride, Grace, R.D. 1, Hartman Rd., North Wales, PA. 19454.
- Mackie, Dr. Gerry L., Dept. of Zoology, Univ. of Guelph, Guelph, Ont. Canada N1G 2W1 (Sphaeriids).
- MacMillan, Gordon K., 169 Glenfield Dr., Pittsburgh, PA. 15235.
- Maes, Dr. Virginia Orr, Dept. of Mollusks, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103.
- Magee, Mrs. Virginia L., Life Science Dept., Mitchell College, New London, CN. 06382 (New England mollusks, both living and Pleistocene).
- Malek, Dr. Emile, Tulane Univ. Medical School, 1430 Tulane Ave., New Orleans, LA. 70112 (Parasitology).
- Malone, Elsie, 2422 Periwinkle Way, P.O. Box 54, Sanibel Is., FL. 33957 (buy-sell-exchange world shells).
- Marshall, Dr. Donald S., Far Lands House, 3414 Halcyon Dr., Alexandria, VA. 22305.
- Marshall, Mrs. Thomas H., 2237 N.E. 175th St., Seattle, WA. 98155 (World shells; exchange).
- Marti, Mrs. Ann, P.O. Box 7, Trinity, AL. 35673.
- Martins, A.M., Frias, Dept. of Zoology, Univ. of Rhode Island, Kingston, RI. 02881.
- Mastenbroek, Paul W., P.O. Box 67, Woodbridge, Ontario L4L 1A9, Canada (Distribution and systematics, Northern North Atlantic Ocean and adjacent seas).
- Mathiak, Mr. and Mrs. Harold A., 209 S. Finch St., Horicon, WI. 53032 (History of Wisconsin mussels: species distribution).
- Mayers, Dan, 648 Wiltshire Dr., State College, PA. 16801 (Studies done on mollusks, classification).
- Mayo, Mrs. Beryl Ivy, 319 Narcissus Rd., Kemah, TX. 77565 (Gulf shallow water and drift mollusks).
- Mazurkiewicz, Dr. Michael, Dept. of Biological Sciences, Univ. of Southern Maine, 96 Falmouth St., Portland, ME. 04103 (Larval development and ecology of estuarine mollusks).
- McBeth, Lewis Dean, 3401 Patio Drive, Erie, PA. 16506 (Collector of worldwide mollusks).
- McCaleb, John E., 782 Worth Blvd., C-41, Pottstown, PA. 19564 (Freshwater mollusks of N.A., esp. Pleuroceridae).
- McCallum, John and Gladys, 4960 Gulf of Mexico Dr., Apt. PH6, Longboat Key, FL. 33548.
- McCarthy, Col. William A., 424 Hunting Lodge Dr., Miami Springs, FL. 33166.
- McCrary, Dr. Anne B., 411 Summer Rest Rd., Wilmington, NC. 28403.
- McGinty, Thomas L., Box 765, Boynton Beach, FL. 33435.
- McHugh, Mrs. John, 4654 Quarry Ridge, Rockford, IL. 61103 (*Murex*).
- McInnes, Mrs. Cornelia G., F-6 Raleigh Apts., Raleigh, NC. 27605 (All Marine).
- McLean, Dr. James H., Los Angeles County Museum, 900 Exposition Blvd., Los Angeles, CA. 90007.
- McLeod, Dr. Michael J., Biology Dept., Belmont Abbey College, Belmont, NC. 28012 (Systematics and evolution).
- McRae, Mrs. Catherine, 1984 Roseate Lane, Sanibel Is., FL. 33957.
- Mead, Dr. Albert R., Assoc. Dean, College of Liberal Arts, Modern Languages Bldg. 347, Univ. of Ariz., Tucson, AZ. 85721.
- Meeder, John F., Rosenstiel Sch. of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Menzel, Dr. R.W., Dept. of Oceanography, Florida State Univ., Tallahassee, FL. 32306 (Oysters; clams).
- Merrill, Arthur and Harriet, National Marine Fisheries Service, Woods Hole, MA. 02543.
- Merritt, Jack H., 2281 Euclid Ave., Ft. Myers, FL. 33901.
- Metcalfe, Dr. Artie L., Dept. of Biological Sciences, Univ. of Texas at El Paso, El Paso, TX. 79968 (Terrestrial Gastropoda of S.W. U.S.).
- Meyer, Mr. and Mrs. Harvey G., P.O. Box 61, Captiva, FL. 33924.
- Michaelson, Eliot, The Shell Gallery, Piccadilly Sq., 77 Union St., Newton Centre, MA. 02159.
- Michelson, Dr. Edward H., 15 Edmands Rd., Apt. 189, Framingham, MA. 01701 (Medical malacology).
- Mikkelsen, Paul and Paula, 508B S. 22nd St., Ft. Pierce, FL. 33450 (Donacidae - Paul; Tellinidae and Littorinidae - Paula).
- Miles, Dr. Charles D., 5100 Rockhill Rd., Biological Sciences Bldg., Kansas City, MO. 64110.
- Miller, Barry B., Dept. of Geology, Kent State Univ., Kent, OH. 44242 (Non-marine Pleistocene, Malacology).
- Miller, Fontelle, 4045 Crayton Rd., Naples, FL. 33940 (Astraeinae).
- Miller, Dr. Walter B., 6140 Cerrada El Ocote, Tucson, AZ. 85718.
- Miser, Wendel L., 1108 Alden Rd., Alexandria, VA. 22309 (Fresh water mollusks).
- Moberg, Capt. (Ret.) A.G., Keene Rd., RFD Box 154, East Free-town, MA. 02717.
- Moller, Gertrude H. Mrs., 2248 University Blvd. South, Jacksonville, FL. 32216.
- Moore, Dr. and Mrs. Donald R. Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Moore, Eric and Eileen, P.O. Box 6606, Orange, CA. 92667.
- Moosmann, Mrs. Robert A. (Margaret), 1025 Kent Rd., Wilmington, DE. 19807.
- Morrison, Dr. J.P.E., 1330 4th St. S.W., Washington, DC. 20024.
- Morrison, Robert W., P.O. Box 15011, Sarasota, FL. 33579 (Marine shells, esp. Cypraea, Voluta, Oliva and Murex).
- Mousley, Louis B., 35350 Panorama Dr., Yucaipa, CA. 92399.
- Murray, Mrs. Francis A., 3741 N.E. 24th Ave., Lighthouse Point, FL. 33064.
- Murray, Dr. Harold D., Biology Dept., Trinity Univ., San Antonio, TX. 78284 (Unionidae; distribution and parasites).
- Murray, Talbot and Miriam, Graduate Sch. of Oceanography, Univ. of Rhode Island, Narragansett, RI. 02882.
- Musick, Mrs. John W. and Richard M. Musick, 1238 E. Bayshore Dr., Virginia Beach, VA. 23451 (Shell collecting for profit).
- Myer, Dr. Donal G., Dept. of Biological Science, Southern Illinois Univ. at Edwardsville, IL. 62026.
- Naide, Dr. Meyer, 2034 Spruce St., Philadelphia, PA. 19103.
- Nelson, Jack and Linda, 116 Rawlings Rd., Gaithersburg, MD. 20760 (*Murex*, *Mitre*, *Cymatium*).
- Nicol, Dr. David, P.O. Box 14376, University Station, Gainesville, FL. 32604.
- Nicolaci, Mr. and Mrs. Domenick, Bella Vista Is., Box 147, Fairhaven, MA. 02719 (*Pecten*; exchange).

- Nilson, Joy S., RFD #1, Box 233, E. Wareham, MA. 02538 (All mollusks of New England area).
- Nielsen, Richard L., Box 278, Fletcher Academy, Fletcher, NC. 28732 (Non-marine aquatic mollusks).
- Nosworthy, Ronald G., P.O. Box 104, 41 Main St., Grand Bank, Newfoundland, Canada AOE 1W0 (North Am. circumboreal mollusks; also Clausiliidae and Turridae).
- Notter, Miss Helen, 2529 Gilmore St., Jacksonville, FL. 32204.
- Nunnally, Sally and Doug Nunnally, 512 North Channel Dr., Apt. B, Wrightsville Beach, NC. 28480.
- Nybakken, Dr. James, Moss Landing Marine Laboratories, Box 223, Moss Landing, CA. 95039.
- Oatis, Bona D., 312 Holiday Park Dr., Pittsburgh, PA. 15239 (World marines; exchange).
- Ode, Dr. Helmer, 4811 Braeburn Dr., Bellaire, TX. 77401 (Gulf of Mexico marines).
- Oesch, D. Ronald, 9 Hill Dr., Glendale, MO. 63122 (Missouri mussel zoogeography).
- Oetzell, Miss Edith M., 518 S. Ardmore Ave., Villa Park, IL. 60181 (*Conus*).
- Old, William E. Jr., Dept. of Mollusks, American Museum of Natural History, Central Park W. at 79th St., New York, NY. 10024.
- Oliveira, Dr. Maury Pinto de, Dept. Biologia-Malacologia, Universidade Federal, DeJuiz De Fora, Cidade Universitaria, 36100 Juiz de Fora, Minas Gerais, Brazil.
- Olsen, Philip L., 10708 Blossom Lane, Silver Spring, MD. 20903 (Capte Hatteras to Cape Cod mollusks).
- Oppenheimer, Dr. Ella H., 7703 Crossland Rd., Baltimore, MD. 21208.
- Orchard, C.D., P.O. Box 115, McQueeney, TX. 78123.
- Ostheimer, Alfred J. III, 3220 Diamond Head Rd., Honolulu, HI. 96815.
- Ostheimer, Mrs. Ruth M., 253 Cumberland, Kendel at Longwood, Kennett Sq., PA. 19348.
- Oswalt, Mrs. Rosellen, 4771 Riverwood Circle, Sarasota, FL. 33581.
- Pace, Dr. Gary L., Univ. of Michigan, Biology Dept., Flint, MI. 48503.
- Paine, Anna, 6918 Lake Kenilworth Dr., Apt. 111, New Orleans, LA. 70126.
- Paine, Walter C., Assoc. Curator, Malacology, Montshire Mus. of Science, 45 Lyme Rd., Hanover, NH. 03755.
- Palmer, Dr. Katherine V.W., 206 Oak Hill Rd., Ithaca, NY. 14850.
- Parker, James Larry and Buddy, 8705 Valleybrook Rd., Birmingham, AL. 35206 (Tropical marine gastropods).
- Parmalee, Dr. Paul W., Prof. of Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916 (Freshwater mollusks from archaeological sites).
- Parodiz, Dr. Juan Jose and Esther, Sect. of Invertebrates, Carnegie Museum, 4400 Forbes Ave., Pittsburgh, PA. 15213 (Neotropical mollusks and freshwater Gastropoda of USA).
- Patch, Diana Craig, 4522 Springfield Ave., Apt. 2F, Philadelphia, PA. 19143 (Grad student in Anthropology, U. of Penn.).
- Penchaszadeh, Dr. Pablo E., Universidad Simon Bolivar, Instituto de Tecnologia y Ciencias Marinas, Caracas, Venezuela.
- Petit, Mr. and Mrs. Richard, P.O. Box 30, North Myrtle Beach, SC. 29582.
- Peyton, Gary, 810 Rose, Denton, TX. 76201 (Environmental chemist: int. in effect of chemical pollutants on mollusks).
- Phillips, Ted, General Delivery, Riviera, AZ. 86442.
- Pierce, Dr. Harold G., Rt. 2, Box 67B, Lexington, VA. 24450.
- Piper, Mr. and Mrs. Emmitt H., P.O. Box 85, Gloucester, NC. 28528.
- Piplani, Shirley A., 26 Jameson Place, West Caldwell, NJ. 07006 (*Chitons*).
- Plockelman, Cynthia H., 311 Franklin Rd., West Palm Beach, FL. 33405 (Caribbean Muricidae, Naticidae).
- Porter, Hugh J., UNC Inst. Marine Sciences, Morehead City, NC. 28557 (Systematics, culture of bivalves).
- Post, Mrs. Alfred P. Jr., P.O. Box 65, Darlington, MD. 21034.
- Pratt, W.L. and Suzann Denton Pratt, Museum of Natural History, Univ. of Nevada, Las Vegas, 4505 Maryland Pkwy. S., Las Vegas, NV. 89154.
- Prezant, Robert S., College of Marine Studies, Univ. of Delaware, Lewes, DE. 19958 (*Anomalodesmata*: mantle structure and function/evolution).
- Pulley, Dr. Thomas E., Director, Houston Museum of Natural Science, P.O. Box 8175, Houston, TX. 77004).
- Racela, Dr. Antonio Jr. and Dr. Luz Racela, 126 W. 116th St., Kansas City, MO. 64114 (Philippine land and marine shells).
- Raeihle, Dorothy and George, 211 Milligan Rd., West Babylon, NY. 11704.
- Raup, Timothy A., 910 Farrell Ave., Kalamazoo, MI. 49007 (*Conus*).
- Raymond, Torrance C., 99 Ridgeview Rd., Poughkeepsie, NY. 12603.
- Reader, Mr. and Mrs. William R., 4772 49th Ave. North, St. Petersburg, FL. 33714 (Live mollusks).
- Reeder, Dr. Richard L., Faculty of Nat. Sci., Univ. of Tulsa, Tulsa, OK. 74104 (Land pulmonates).
- Rehder, Dr. Harald A. and Lois C., 5620 Ogden Rd., Washington, DC. 20016.
- Rice, Thomas C., Of Sea and Shore Publications, P.O. Box 33, Port Gamble, WA. 98364.
- Richards, Charles S., Lab. of Parasitic Diseases, National Institute of Health, Bethesda, MD. 20014 (Freshwater mollusks, host-parasite relations, mollusk pathology and genetics).
- Riggle, Stan, 26 E. Market St., Iowa City, IO. 52240.
- Rios, Dr. Eliezer de C., Box 379, Museo Oceanografico, Rio Grande, RS, 96200, Brazil.
- Ritchie, Mrs. Robert M., 17 Country Club Pl., Bloomington, IL. 61701.
- Roach, Frank and Joan D., 1028, Belvoir Rd., Norristown, PA. 19401 (Specializing in *Cardium*, *Chama*, and *Pecten*).
- Roberts, Mr. and Mrs. H. Wallace, Hopkinson House, Apt. 2816, Washington Square South, Philadelphia, PA. 19106 (Marine).
- Robertson, Dr. Robert, Dept. of Malacology, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (Marine).
- Root, John, P.O. Box 182, West Palm Beach, FL. 33402.
- Roper, Dr. Clyde F.E., Div. of Mollusks, U.S. National Museum, Washington, DC. 20560 (Systematics and ecology of Cephalopoda).
- Ropes, John W., P.O. Box 56, Pattee Rd., Teaticket, MA. 02536.
- Rosewater, Dr. and Mrs. Joseph, Dept. of Invertebrate Zoology (mollusks), USNM of Natural History, Washington, DC. 20560.
- Roth, Barry, Dept. of Geology, Calif. Academy of Sciences, San Francisco, CA. 94118.

- Rotter, Dr. Saul D., 170 North Ocean Blvd., Palm Beach, FL. 33480 (Cones, Volutes, Cowries, Olives).
- Roworth, Edwin C., 1361 Windsor Rd., Cardiff-by-the-Sea, CA. 92007 (World shells and sea life).
- Russell, Charles E., 10602 Jordan Rd., Carmel, IN. 46032 (land; freshwater shells).
- Russell, Dr. Henry D., 50 Springdale Ave., Dover, MA. 02030.
- Russell, Dr. Loris S. Royal Ontario Museum, 100 Queen's Park, Toronto, Ont., Canada M5S 2C6.
- Russell-Hunter, Dr. W.D., Dept. of Biology, 112 Lyman Hall, Syracuse Univ., Syracuse, NY. 13210.
- Rutter, Kurt L., P.O. Box 107, Stanton, NJ. 08885 (Shells of the littoral area).
- Sage, alter E. III, 1123 Hathaway, Louisville, KY. 40215.
- Sartor, James C., 5606 Duxbury, Houston, TX. 77035 (Microscopic marine mollusks — exchange or purchase).
- Scarabino, Sr. Victor, Instituto de Investigaciones Biologicas, Avda. Italia 3318, Montevideo, Uruguay.
- Schell, Mr. and Mrs. Frederic B. Jr., 1200 Peppertree Lane, Apt. 102, Sarasota, FL. 33581 (winter); The Rooklands, Colebrook, CT. 06021 (June 1-Nov. 1).
- Scheuerman, Clara, 1366 Twinsburg Rd., Macdeonia, OH. 44067 (Harpa, Cypraea, helmets).
- Schilling, Mr. and Mrs. Albert E., 419 Linden Ave., Glenside, PA. 19038 (Mr. *Cypraea*; Mrs. *Murex*; both, *Conus*).
- Schilling, Mrs. Frieda, 3707 Lan Dr., St. Louis, MO. 63125.
- Schriner, Miriam W. and Howard Jr., Rt. #2, Box 127, LaBelle, FL. 33935 (Paleo-malacological research).
- Schuyler, Clint, 229 East Allen St., Lancaster, OH. 43130 (Collecting and studying shells).
- Seip, William F., 1555 Stonewood Rd., Baltimore, MD. 21239.
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- Shaw, William N., 209 Sycamore Ave., Easton, MD. 21601 (Shellfish culture).
- Shimek, Ronald, Dept. of Biological Sciences, Univ. of Alaska, 3221 Providence Dr., Anchorage, AK. 99504 (Turrid gastropods, gastropod systematics, subtidal benthic marine ecology).
- Shoemaker, Alan H., 2136 Rolling Hills Rd., Columbia, SC. 29210 (littoral and shallow sublittoral mollusks).
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NOTICES

The Forty-Fifth Annual Meeting of the American Malacological Union will be held in Corpus Christi, Texas, the week of Aug. 5-11, 1979. This will be a joint session, hosted by AMU, with the Western Society of Malacologists. Headquarters will be the La Quinta Royale motor inn one block from the shoreline. Direct inquiries to AMU President William E. Old Jr., Dept. of Invertebrates, American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024.

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BULLETIN OF THE AMERICAN MALACOLOGICAL UNION

for 1979

**COVERING THE
FORTY FIFTH
ANNUAL MEETING**

Corpus Christi, Texas

August 5-11, 1979

**Joint Meeting with
Western Society
of
Malacologists**



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**BULLETIN OF
THE AMERICAN
MALACOLOGICAL
UNION**

for 1979

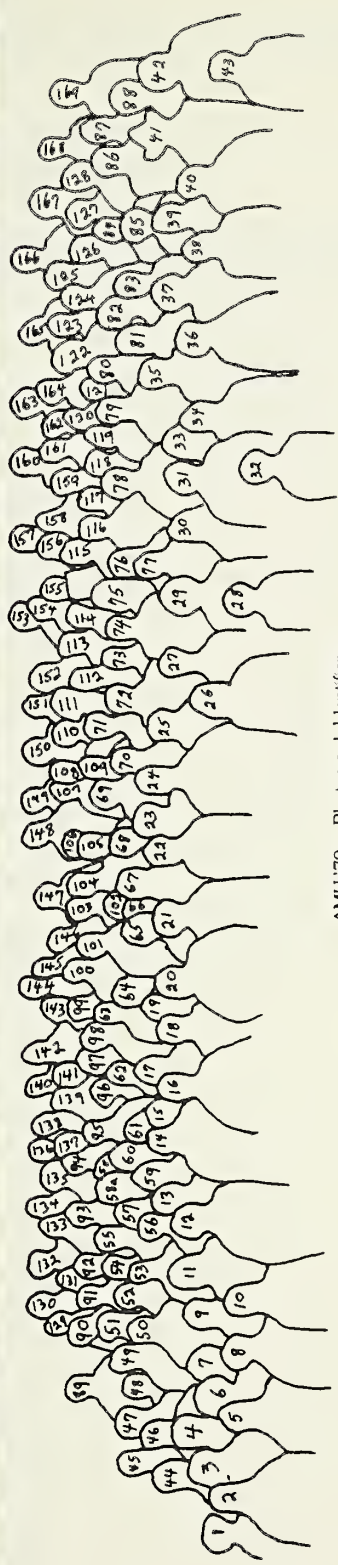
**COVERING THE
FORTY FIFTH
ANNUAL MEETING**

Corpus Christi, Texas

August 5-11, 1979

**Joint Meeting with
Western Society
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THE AMERICAN MALACOLOGICAL UNION, INC.

FORTY-FIFTH ANNUAL MEETING

August 5-11, 1979
Corpus Christi, Texas

AMU's second meeting in Corpus Christi, Texas was a joint session of the American Malacological Union and the Western Society of Malacologists, hosted by AMU, with the Coastal Bend Shell Club of Corpus Christi the local organization. One hundred and ninety-eight registrants came from as far away as Venezuela, Hawaii, England, Mexico, Brazil, Chile, and Canada.

A record number of over 100 papers was presented. President William E. Old, Jr. accepted an abundance of papers on a great variety of subjects concerning mollusks in his efforts to make this joint session of interest to everyone and to be assured that he would have full sessions. That he did, indeed. However, though the sessions started early and lasted late, there seemed also to be time for socializing and entertainment in true Texas style.

There was a number of students at this meeting, some giving papers in the first competition for an award for a student paper, initiated by President Old and to be continued by AMU.

Not many years ago, most AMU members chose to arrive on the Monday of the week beginning the annual meeting. Since it has become somewhat of a custom for the president to have a reception or get-together on Sunday evening for early arrivals, it is now noticed that almost everyone tries to arrive for this event. There was a bumper crowd registering on Sunday. Entertainment began early also. Exhibits of Texas mollusks were set up by Corpus Christi State University students, and some fine exhibits were brought by members Bill Bledsoe and Lee and Stu Armington. Audrey and Wayne Holiman presented a continuous slide show on former meetings. The party given by Bill Old and members of the Corpus Christi shell club at nearby Ramada Inn was well attended, the shrimp and other food and drink kept everybody busy in the elbow-to-elbow atmosphere that really introduced everyone to the reason why Texans need air conditioning most of the year.

Monday morning was busy with the open meeting on conservation and registration. A meeting of the AMU Council of Systematic Malacologists was held also.

President Old opened the session at 1:30 p.m. in La Salle Grande of La Quinta Royale Motor Inn, welcoming our members and members of the Western Society of Malacologists. President Barry Roth of WSM responded, other greetings were extended to visitors, the papers were set to begin and continued to 5:30 p.m.

That evening, members gathered in the lobby for a walk up the hill to the Texas Stompede scheduled in the Petroleum Club. What's a Stompede? Well, that's a Texas party complete with square dancers, some Western dances, lots of food and drink, a try at finding new partners in Paul Jones circles, visiting and fun.

Tuesday's sessions began at 9 a.m. at La Quinta. At noon everyone boarded buses to go to the Corpus Christi Museum, first for the group photo, and then to attend the symposium on life histories of mollusks presented in the museum auditorium from 2 to 5 p.m.

Friends of the Museum were ready with a cocktail party at the

end of the papers. Later a program with Mexican dancers was offered, and the Museum accepted from AMU member Carl T. Young, Jr., of Corpus Christi, his collection of mollusks. The Mexican supper was beautifully planned and executed.

The Shell Night event, chaired by Constance Boone, started a little late and ended even later, but those who attended were enthusiastic about the program of speakers presenting slides, movies and talks on the whooping crane (David Blankinship), diving for shells in Southeast Florida (Gene D. Everson), trailing mollusks in Baja California (Audrey and Wayne Holiman), and search and discovery of *Strombus taurus* (Dr. W.W. Sutow).

A popular introduction to the shell night event was the tables of freebie shells and shell club publications offered visitors. These disappeared so fast that perhaps this event could be repeated as part of a future shell night.

Wednesday's sessions back at LaQuinta Royale started at 8:30 a.m., continuing the fine symposium on life histories of mollusks. At noon the AMU Executive Council and WSM Executive Council met for business. That afternoon Dr. T.E. Pulley chaired a symposium on mollusks of the Gulf of Mexico, including a history of the exploration and research in and around the Gulf by Dr. Donald Moore. The hour and half symposium included talks on both shallow water mollusk assemblages of the Gulf and a report on four new records of Aplocophorous mollusks from the South Texas continental shelf.

That evening there were papers given on all kinds of mollusks and uses of them in Texas. This was followed by a super party given by members from the Philadelphia area.

Two concurrent sessions, one on freshwater mollusks and the other on Cephalopods, were held on Thursday morning. Papers continued in the afternoon to 2:30 p.m. when the AMU general meeting convened, followed by the WSM general meeting.

The meeting was formally over, but the traditional banquet was held that evening with a record number of members and guests in attendance. Both organizational presidents introduced officers. Awards were discussed and announced. Dr. Dorothea Franzen presented the \$100.00 check to student Robert S. Prezant for his report on mantle glands of the Lyonsiidae.

Next day started early for some 30 field trippers going to Mansfield Cut on Padre Island by jeep. Others chose from field trips to dive on the oil rigs, to visit Welder Wildlife to seek land snails, to invade rivers in search for fresh water mollusks, to wade in shallow bays for elusive mollusks, or to walk the beach at Mustang Island or examine rocks brought up by snorkelers. By nighttime, members straggled in the motel, gathered to talk and review the day and ended up joining the Philadelphia members for some socializing.

There was a general feeling that this had been another good time in Texas.

Constance E. Boone

CONTRIBUTED PAPERS PRESENTED AT THE 1979 MEETING

MOLLUSCAN EXPLORATION AND RESEARCH IN AND AROUND THE GULF OF MEXICO

Donald R. Moore

Associate Professor,

Rosenstiel School of Marine and Atmospheric Science
University of Miami, Miami, FLA 33149

Peter Dance (1966) quotes Mawe (1825) as saying, "The coasts of Georgia and North and South Carolina produced many beautiful species, particularly of *Oliva*, but of the testaceous productions of the island of New Orleans, the Mississippi, and the whole of that range, we have obtained but little information."

The Gulf of Mexico was first seen by Europeans (we think) around the year 1500. Morrison (1974), states that it was Ponce de Leon in 1513, but the Waldseemuller map of 1507 clearly shows Florida and the Gulf. At any event, the Gulf was rapidly explored within a few years. Ponce de Leon anchored off what was probably the mouth of the Caloosahatchee in 1513, then sailed down to the Yucatan coast after the Caloosahatchee proved unfriendly. Then in 1518 the northern Gulf was explored around to the mouth of the Panuco in Mexico by Pineda. By this time, Cortes had sailed to Mexico, and the Gulf became a well known place.

For a long time thereafter, progress was slow. The Gulf became better charted, but little real progress on the study of Gulf mollusks was made until well into the 19th century. Then T.A. Conrad (Wheeler, 1935) visited Alabama to collect Claiborne and other Eocene fossils. While there, in April-May, 1833, he visited Mobile and Mobile Point. He was there again early in 1834. In the winter of 1842, Conrad (1846) joined an expedition led by Commander Powell that was sent to survey Tampa Bay. Conrad's particular mission was to collect Miocene fossils. He collected recent material as well. Conrad described Gulf of Mexico species over a period of more than thirty years, some as fossils which were later found to be still living species.

Little was done for some years after Conrad's stay at Fort Brooke (Tampa). During the Civil War, Fort Brooke was occupied by rebel forces (Jahoda, 1973). After the war, three friends, R.E.C. Stearns, William Stimpson, and Col. E. Jewett, began collecting along the west coast of Florida (Stearns, 1879). Stimpson dredged the west Florida shelf in 1872, but he was a sick man, both mentally and physically, having lost all his books and collections in the great Chicago fire. We know that another collector was busy at that time, for Calkins (1878) mentions that Dr. J.W. Velie met Stimpson in Key West, just a few weeks before Stimpson's death. Stimpson's plans for publishing on the fauna of western Florida never materialized, and Stearns described only a few species.

At this time, some very important work was being conducted by the U.S. Coast Survey. Actually, it was a continuation of work begun by the Survey in 1845 (Galstoff, 1954). The survey of the continental shelf in the Gulf had been carried out by the British Admiralty, and, to some extent, by the U.S. Navy. Then the Coast Survey began its systematic exploration (i.e., soundings) of the Gulf in 1872. It was begun by Commander Howell, USN, along the west coast of Florida in fairly shallow water (Agassiz, 1888). It was continued and brought to a successful conclusion by Lt. Commander Sigsbee in 1875-78. Wire soundings were begun on the "Blake" in 1874, and this was much better and faster than

the use of rope. Deep sea dredging and trawling had already begun with Pourtales on the "Corwin" and "Bibb", and, in December of 1877, the "Blake" commenced a deep water biological survey of the Gulf and adjacent areas. Only the first of the famous three cruises occurred in the Gulf and this was confined to the southeastern Gulf and the west coast of Florida. Further work from the southwest coast of Florida to off the mouth of the Mississippi was done by the "Albatross" in 1885.

Dall (1880, 1881, 1886, 1889) began publishing the results of the "Blake" cruises and also material collected by the U.S. Fish Commission vessel, the "Albatross." Dall included discussion of the shallow water fauna in these publications, making them important to all marine malacologists. By this time, Dall had begun a monumental study of Neogene paleontology of Florida, and which also incorporated considerable material on living species. He was anticipated in this work by Angelo Heilprin (1887), who, together with Joseph Willcox, made an expedition to the Caloosahatchee River early in 1886. Dall, of course, had traveled to Florida as early as the winter of 1884-85, and had made at least two of these trips before the 1891 trip mentioned by Bartsch, Rehder, and Shields (1946). The Supplement to Heilprin's (1887) paper contains the statement that these additional specimens were collected along the Caloosahatchee by Dall and Willcox, but had been brought in too late to be included in the main body of the paper. Dall (1890-1903) made a major study of the Caloosahatchee area, and produced a monumental work in which many living molluscs were discussed and sometimes described as well as hundreds of extinct species.

The western Gulf had excited little interest, but in one early work (Roemer, 1849), a list of shells from Galveston was published. The Marquis de Folin (1870) described new species of micromolluscs from Carmen, a port city in the extreme southern part of the Gulf, and also from Vera Cruz. Folin had asked ship captains to bring back bottom sediments to France, so this is how he obtained Gulf of Mexico material. Heilprin (1891) made a survey of the corals and coral reefs around Vera Cruz: the shells collected were published on by F.C. Baker (1891). Additional work was the report by Hinkley (1907) on shells collected in northeastern Mexico.

Dall described several marine species from Texas during the 1890's. One of these, *Callocardia texasiana*, was collected by Wurdeman during the earliest Coast Survey work on the Texas Coast (about 1856; Dall, 1892). Singley, (1893) published an extensive list of Texas coast molluscs, but many names were apparently included because they had been listed in other publications as occurring from North Carolina to Brazil. Mitchell (1894) privately published a list of 81 species actually living along the Texas coast.

Most of the action, however, was along the west coast of Florida. Calkins (1878) listed the material he had collected during the course of two winters in Florida. At this time there were almost no shells of the southeast Atlantic coasts in the National Museum; they had all been lost in the great Chicago fire of 1871 (Dall, 1884). This last paper by Dall identified a small collection made by Henry Hemphill. The next notable paper was by Charles T. Simpson (1887-1889) whose list mentioned a great number of localities and habitats, and from his comments was obviously the result of years of collecting. Simpson (1892) was in the Tampa Bay area with John B. Henderson during the winter of 1891-92.

He noted that the area had been worked over by Agassiz, Conrad, Stimpson, Spinner, Stearns, Dall, Velie, Calkins and many others. Even Joseph Willcox (1894, 1896), Heilprin's companion on the Caloosahatchee, wrote two papers on west Florida molluscs.

At about this time, Clarence B. Moore was traveling around the Gulf coast. His interest was mainly archeology, Indian shell mounds, and the like, but he also collected shells. Many of these were sent to the Philadelphia Academy, and a collection from northwest Florida, and Horn Island, Mississippi, was written up by Vanatta (1904). Stearns (1894) gave a very short list of marine species from Mississippi, but Cary (1906) enumerated 73 species from the Louisiana coast.

The Bureau of Commercial Fisheries sent H.F. Moore (1907, 1913a, b) to the Gulf to study shallow bays and lagoons with oyster raising potential. These papers described existing oyster reefs, and mentioned other molluscs if they preyed upon or competed with oysters. Even before this, Adams and Kendall (1891) had reported on the fishing grounds off the west coast of Florida.

Maury (1920, 1922) was the first to publish a paper listing the molluscan fauna of a wide area of the Gulf. She listed the recent shallow water fauna from Tampa to Corpus Christi, the deep water fauna dredged by the "Blake", and Upper Cenozoic fossils from the Gulf States. This was a valuable contribution, but, unfortunately, has been virtually unknown to biologists working in the Gulf. Many of the records for shallow water species were based on collections made by Gilbert Harris, founder of the Paleontological Research Institution. This paper was followed by the better known checklist published by Johnson (1934) which, however, covered a much larger area.

Clench (1923, 1925, 1929) wrote two of his early papers on Sanibel molluscs and a later one on the Mississippi Delta area. Clench picked up malaria on one of his southern trips, and cured himself as physicians in Michigan were not familiar with the disease. Haas (1940) also wrote on Sanibel molluscs, but from the ecological point of view. Harry (1942) published a list of species collected near the now defunct Louisiana State University Marine Laboratory at Grand Isle from 1929 to 1941.

Another Texas list was published posthumously by Strecker (1935). It recorded 188 species plus an appendix of 176 species reported by Dall to come from Texas, but for which Strecker had no locality data. Stenzel (1940) published a list of 56 species from Port Isabel, at the extreme southern tip of Texas. This work was continued by Pulley (1949, 1952), and the second paper was the first really comprehensive list of Texas molluscs. Ladd (1951) worked on assemblages of invertebrates in Texas bays, but concentrated on the molluscs.

Offshore exploration had virtually ceased after the preliminary work done by the "Blake" and "Albatross". In 1950, however, the Fish and Wildlife vessel "Oregon" was assigned to the Gulf in conjunction with the establishment of a small Fisheries laboratory in Pascagoula, Mississippi. Two laboratory directors, Stewart Springer, and then Harvey Bullis, undertook the collection and preservation of many thousands of specimens of both plants and animals in addition to their regular fishery work. Bullis took the molluscs as his special area, but soon had all of his time taken up with fishery work. The collections he made have all been shipped to the National Museum of Natural History. Bullis (1956) wrote one paper on Gulf molluscs, and collaborated on two lists of species from the "Oregon" and "Silver Bay" collections (Springer and Bullis, 1956, and Bullis and Thompson, 1965). The cephalopods were shipped to Miami, and Voss (1956) re-

ported on the bulk of these in a review of the cephalopods of the Gulf of Mexico. This is still the definitive paper for these animals in the Gulf although more people are now showing interest in this branch of the Mollusca. Voss and Solis-Ramirez (1966) described the commercial octopus of the southern Gulf because Solis tried to raise this octopus from the egg. Everyone had thought that it was *Octopus vulgaris*, but the eggs were large and produced young by direct development. Voss examined specimens and found it to be an undescribed species. It was named *Octopus maya* after the native inhabitants of Yucatan.

The Gulf coastal region began to be much more developed in the 1950's. Along with the increasing population there was a greater interest in the Gulf and its resources. Several marine laboratories were established: The Institute of Marine Science, University of Texas at Port Aransas; Gulf Coast Research Laboratory, Ocean Springs, Mississippi; The Oceanographic Institute, Florida State University at Alligator Harbor; and the Marine Research Laboratory, Department of Natural Resources, State of Florida at St. Petersburg. All of these laboratories did some work to collect, identify and tabulate the marine invertebrate fauna of the Gulf. They were helped to some extent by a Fishery Bulletin of the Fish and Wildlife Service, Galtsoff, Ed. (1954) in which various specialists contributed chapters that covered what was known about each group of animals in the Gulf. Rehder (1954) discussed the shelled molluscs and their distribution, while Voss (1954) wrote on the cephalopods.

The past three decades have also seen the establishment of marine scientific journals devoted to the study of the Gulf and adjacent areas. The Publications of the Institute of Marine Science, University of Texas, started in 1945. The Bulletin of Marine Science of the Gulf and Caribbean, University of Miami, followed in 1950. Its name has since been shortened to Bulletin of Marine Science and the Texas publication is now known as Contributions in Marine Science. Gulf Research Reports, Gulf Coast Research Laboratory, began in 1961 with a mollusc paper by Moore (1961). The latest to appear is Northeast Gulf Science published by the Dauphin Island Sea Lab, Dauphin Island, Alabama. The Marine Research Laboratory at St. Petersburg, Florida, has published various types of papers, but they are produced individually and not as a journal. Other journals also publish on various aspects of scientific work in the Gulf, and one shell club bulletin, The Texas Conchologist, has published a large amount of information on marine molluscs in the northwestern Gulf. Most of this has been written by Helmer Ode over a fifteen year period (1964-1979).

We have mentioned the beginning of Gulf Coast marine laboratories, and fishery investigations by the Fish and Wildlife Service, but several other factors influenced the collection and study of molluscs. Shrimpers were persuaded to bring in shells by affluent collectors. Some of these specimens reached museums. Oil companies also studied the Gulf fauna using vessels of various sizes. Very little on this material has been published, however. Funds provided by oil companies did support ecological surveys in the northern Gulf, Parker (1956a, b, 1960), and a large number of graduate students have been helped in their research. Some amateurs took up dredging, but these people were often amateurs in name only. Maxwell Smith was an early dredger (1937), as well as Tom McGinty (Schwengel and McGinty, 1942) and Frank Lyman (1942). Most amateur dredgers worked in fairly shallow depths, but Leo Burry (personal observation) dredged out to about 1000 m. Jim Moore, a dealer on the Florida west coast, dredged out to around 400 m, and sold bottom material by the bushel basket. You bought it, then you had to

hunt for your own shells. Riley Black, a west coast shrimper, divided his time between shrimping and dredging for shells, and he also sold bottom material by the basket.

The Mexican coast was now attracting more interest. First Moore (1959) listed the molluscs of Blanquilla Reef, then Rice and Kornicker (1962, 1965) published on the molluscs of Alacran Reef and vicinity. The Mexicans also began a study of their coastal waters starting with the big lagoons on the Gulf coast. This work was under the direction of Agustin Ayala-Castanares, and the molluscs were reported on by Garcia-Cubas (1963, 1968). Further research on the Gulf coast of Mexico was a dissertation study by John W. Tunnell, Jr. (1974), on the molluscs of two coral reefs near Cabo Rojo and Vera Cruz.

A very ambitious benthic sampling program was begun by the St. Petersburg Marine Research Laboratory in 1965. Ten stations were sampled monthly for a period of 28 months, Lyons (1969). A large amount of material was collected and sorted at the laboratory. Most of it remains to be worked on, although Lyons (1972, 1978) has published on some species.

Work far offshore has been important during the last several years. Lipka (1974) published a list of molluscs from the Flower Garden Banks. The same year saw the start of Bureau of Land Management (a Federal Agency) surveys in the Gulf. This program was never well organized and was much more oriented toward the accumulation of data than a serious scientific study. However, some published work has come out as a result of this work, Moore (1977), Hopkins, et al (1977).

Before closing, I should mention several books. The first was by Perry (1940), and concerned the shallow water molluscs of the southwest coast of Florida. It was revised and brought up to date with Jeanne Schwengel as second author and new photographs by Axel Olsson, Perry and Schwengel (1955). Olsson, et al (1953) published a book on Upper Cenozoic paleontology of southwest Florida, but, as it figured and described many living molluscs, it was an important work for zoology as well. A book on shells of the Texas coast was written by Andrews (1971). This was more than a simple identification manual, and was a very welcome addition to the literature. It was revised recently, Andrews (1977) and can be recommended especially for the excellent photographs.

Much work has been accomplished, and the shallow water fauna of the Gulf is becoming much better known. There are still large areas of the continental shelf that need research, especially in the southern Gulf, and the slope and Sigsbee Abyssal Plain should provide a vast study area for many years to come.

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A CLOSE LOOK AT *LITTORINA* RADULAE

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Scanning Electron Microscope studies have been carried out on eastern Pacific Littorinidae. Four groups of species each exhibiting a different kind of radula have been noted and have counterparts in other world faunal areas where radulae of Littorinidae have been delineated.

The Littorinid radula is well illustrated in Fretter and Graham (1962, their fig. 12). It is attached to the radula membrane in numerous transverse rows, the entire ribbon often exceeding the length of the shell. Each transverse row consists of a central tooth, the rachidian, on either side of which there is a large lateral tooth, a narrower inner marginal tooth and a still more slender outer marginal. Each tooth bears a number of cusps at its anterior end and is characteristically shaped. The laterals have a wide basal notch which I call the "littorinid embayment" (see Rosewater, 1970, pl. 238).

The "rhomboidal" radula with a broad, often multicusped rachidian is common to cold water Littorinidae inhabiting arctic and antarctic (Arnaud and Bandel, 1978) to boreal seas. This radula probably is useful in feeding activities involving macroscopic green and brown algae. A representative eastern Pacific species exhibiting the "rhomboidal" radula is *Littorina sitkana* Philippi, 1846 (see figs. 1, 2). Other northern and eastern Pacific species with the "rhomboidal" radula are *Littorina newcombi*ana, *L. aleutica*, *L. atkana*, *L. squalida*, *L. tenebrosa* and *L. brevicula* (Rosewater, all this study). Inhabitants of other faunal areas that possess "rhomboidal" radulae are: eastern and western Atlantic: *L. littorea* (also introduced into eastern Pacific (Carlton, 1969)), *L. saxatilis* and *L. obtusata* (all Bandel, 1974); Indo-Pacific (south Temperate): *Laevilitorina mariae* (Ponder and Rosewater, in press); Antarctic: *Pellilitorina setosa* and *P. pellita* (Arnaud and Bandel, 1978).

Several tropical eastern Pacific species possess a highly distinctive radula that I term "hooded," marked by the presence of a frontal plate anterior to the rachidian cusps (Bandel, 1974). This structure, the precise function of which is unknown, is present in the radulae of several tropical and at least one temperate species that live on pilings, mangrove, driftwood or marsh grass. The frontal plate must aid in feeding on plant material growing on the surface of the wood or grass. *Littorina varia* Sowerby, 1832, exhibits the "hooded" radula (see figs. 3, 4). Other tropical eastern Pacific species with "hooded" radulae are *Littorina scab-*

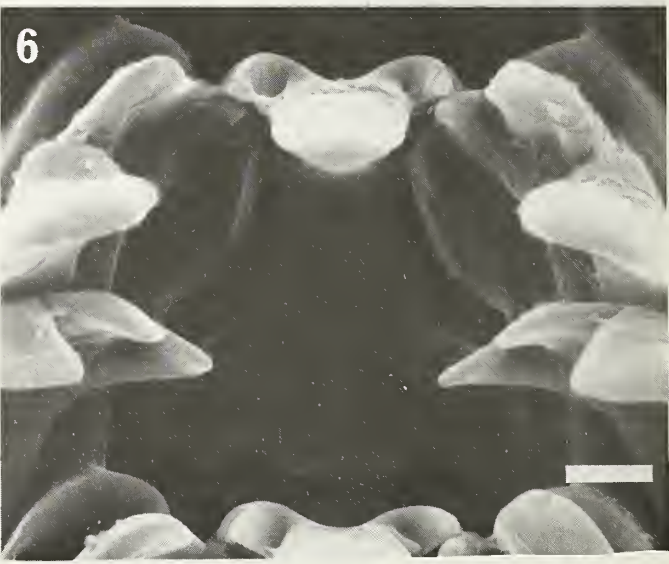
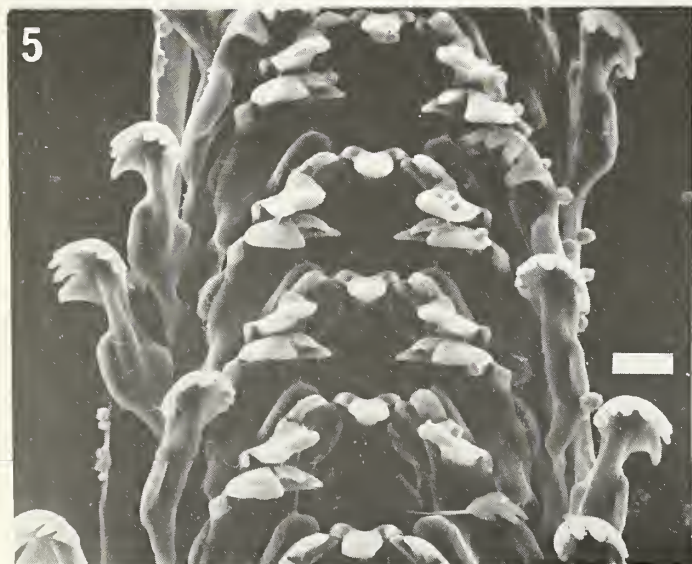
ra aberrans, *L. zebra*, and *L. fasciata* (Rosewater, all this study). Species in other faunal areas that possess "hooded" radulae are: western Atlantic: *L. irrorata* (Troschel, 1858), *L. nebulosa* (Troschel, 1858; Bandel, 1974), *L. flava* (Marcus and Marcus, 1963; Bandel, 1974); eastern and western Atlantic: *L. scabra angulifera* (Bandel, 1974); Indo-Pacific: *L. scabra scabra*, *L. melanostoma* and *L. carinifera* (Rosewater, 1970).

Remaining eastern Pacific littorines all possess one or the other of two kinds that I term "moderate" and "pick" radulae. The two may be parts of a continuum although they seem in this faunal area to form two rather discreet groups. The "moderate" radula exhibited by *Littorina keenae* Rosewater, 1978 (figs. 5, 6) is narrower than the "rhomboidal," but does not possess the pointed cusps of the "pick" type (q.v.). It is present in species inhabiting both north and south temperate areas and also occurs in the antarctic. Although having no outstanding anatomical features it is, no doubt, a successful food-gathering organ for some animals living in the spray zone on rocks. Other eastern Pacific species with "moderate" radulae are *L. scutulata*, *L. peruviana* and *L. fernandezensis* from north and south temperate zones, respectively (Rosewater, all this study); western Atlantic: *Littorina ziczac*, *L. mespillum*, *L. meleagris* and *Tectarius mucicatus* (all Bandel, 1974); eastern Atlantic: *L. nenitoides* (Bandel, 1974).

The "pick" radula is exhibited by a number of mainly high shore rock dwelling tropical eastern Pacific species. An example is *Littorina angustostoma* C.B. Adams, 1852 (see figs. 7, 8). This radula, characterized by sharpened, pick-like cusps, may abrade microvegetation baked onto rock surfaces by the hot tropical sun. Other eastern Pacific species with "pick" radulae are *Nodilittorina galapagensis*, *Littorina penicillata*, *L. paytensis*, *L. pullata*, *L. araucana*, *L. modesta* and *L. aspera* (Rosewater, all this study). In the western Atlantic it is present in *Nodilittorina tuberculata*, *N. dilatata*, *Littorina jamaicensis*, *L. lineolata*; eastern Atlantic: *Nodilittorina striata* and *L. punctata* (all Bandel, 1974).

None of the eastern Pacific species so far examined exhibit the extremely reduced "vestigial" rachidian found in *Echininus*, some *Tectarius*, or in certain Indo-Pacific or Caribbean species (see Abbott, 1954; Bandel, *ibid.*; Rosewater, 1972). It appears that representatives of those generic groups are absent from the eastern Pacific.

Five major kinds (only four in the eastern Pacific) of Littorinid radulae: "rhomboidal," "hooded," "moderate," "pick," and "vestigial" appear to be distributed among the hundred or so recognizable species in the family throughout the world (see Lists of Recognized Taxa in Rosewater, 1970, 1972). The four kinds of radulae present in eastern Pacific species appear to be correlated



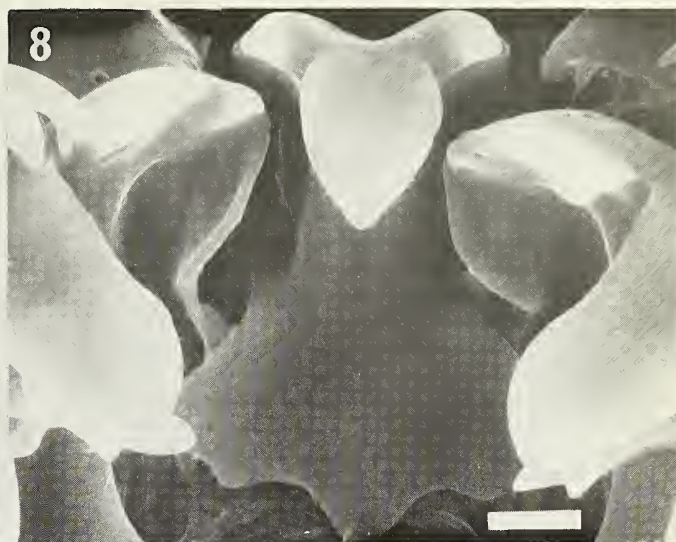


PLATE CAPTION

Scanning Electron Micrographs of *Littorina* Radulae
 Figs. 1, 2. *Littorina sitkana* Philippi; Cook Inlet, Alaska; female (USNM 796243). Fig. 1. "rhomboidal" radula, showing 4 complete transverse rows. Bar = 50 μ , 270X. Fig. 2. "rhomboidal" rachidian (note: "flag" on central cusp is an anomaly). Bar = 10 μ , 1000X.
 Figs. 3, 4. *Littorina varia* Sowerby; Fort Amador, Canal Zone; female (USNM 733000). Fig. 3. "hooded" radula, showing 3 nearly complete transverse rows. Bar = 50 μ , 250X. Fig. 4.

"hooded" rachidian. Bar = 10 μ , 850X.
 Figs. 5, 6. *Littorina keenae* Rosewater; near Tijuana, Mexico; male (USNM 796242). Fig. 5. "moderate" radula, showing about 4 complete transverse rows. Bar = 25 μ , 320X. Fig. 6. "moderate" rachidian. Bar = 10 μ , 1200X.
 Figs. 7, 8. *Littorina angiostruma* C.B. Adams; north shore Taboguilla Island, Panama; female (USNM 733868). Fig. 7. "pick" radula, showing about 2 complete transverse rows. Bar = 10 μ , 800X. Fig. 8. "pick" rachidian. Bar = 5 μ , 2500X.

with: 1. geographical location, i.e., arctic, boreal, temperate and tropical life zones; 2. feeding ecology, i.e., inter- or subtidal, spray zone, shore vegetation, or high shore rocks.

The systematist probably would attempt to base genera or subgenera on these groupings and, in many cases, they do seem to support at least the subgeneric level of importance. In deriving the evolution of these kinds of radulae several possibilities are apparent. It is obvious that the radulae that are most efficient for specific feeding jobs have arisen in response to selection. The "rhomboidal" may handle best the macroalgae that thrive in cold water; the "hooded" may work well with the sort of vegetation that grows best on mangrove; the "moderate" -algal vegetation of the spray zone; and the "pick" -baked-on algal vegetation of the tropics. Because the four kinds of radulae also seem to have some geographic basis, it may be reasonable to suggest that species exhibiting them have evolved under conditions similar to those under which they are now living either near where they are presently distributed or that they have migrated following these conditions as they changed through geologic time.

The extremely clear high magnifications possible with SEM permit close examination of the Littorinid radula. It is thus possible to understand how the processes on the several teeth interdigitate with fossae on others, and how the radula folds and unfolds as it is pushed out of a snail's mouth and pulled back again during feeding activities as described by Ankel (1936, 1937; also see Fretter and Graham, 1962). One of the more striking tooth relationships is that of the fitting of the inner marginal tooth shaft into the littorinid embayment of the lateral tooth which is extremely difficult to observe with an ordinary light microscope.

ACKNOWLEDGEMENTS

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THE GLADIUS OF THE SQUIDS, AN UNUSUAL MOLLUSCAN SHELL

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As is true of the majority of mollusks, the teuthoid cephalopods or squids, possess a shell called the pen or gladius. Both its composition and anatomical placement, however, are different from those of the more commonly known molluscan groups. The gladius is composed of chitin, a proteinaceous substance secreted by the shell sac, a membranous envelope that surrounds the shell. The gladius is located internally in a mid-dorsal position, lying longitudinally just beneath or embedded within the dorsal mantle musculature. In most species, the gladius extends from the anterior tip of the dorsal lappet to the posterior terminus of the mantle.

The recent teuthoid gladius represents one of several end products in a series of parallel evolutionary lineages derived from the ancient nautiloid and ammonoid shells. These external shells, more typically molluscan, were heavily calcified, straight or planospiral structures containing septa, compartmentalizing the shell, and a siphuncle connecting each chamber, for the purpose of gas volume regulation. The outermost compartment, the living chamber, served to house the animal. Septal lines, usually visible on the outer wall of the shell surface, aid in the taxonomic classification of these groups. Other lineages led to the remainder of the coleoid groups, each with their characteristic shell; the cuttlebone in the sepiids, the ramshorn shell in *Spirula*, the gladius in the vampyromorphs, and the more puzzling shell vestiges and stylets in the octopods. Each of these evolutionary lines, diverging approximately in the Triassic (Jeletzky, 1966), demonstrate progressive uncoiling, overall size reduction, and internalization of the shell.

The belemnite shell, a Jurassic cousin to the modern coleoids, while not in the direct line leading to the recent squids, does serve to illustrate an intermediate position in this process of reduction. The belemnite shell is composed of three main elements (Figure 1). The first component is the guard or rostrum, a sturdy, conical structure constituting the posterior portion of the shell. Composed of calcite prisms, the rostrum may have served as a counterweight to offset the buoyant effects of the gas filled phragmocone, allowing the belemnite to maintain a horizontal position in the water (Flower, 1961; Donovan, 1964). Due to the solid nature of the rostrum, it is often the only portion of the belemnite shell to be fossilized.

Moving anteriorly, the next region of the belemnite shell is the phragmocone. Lying within the concavity of the rostrum, the phragmocone is composed of chambers separated by septa and linked by a ventrally displaced siphuncle. The phragmocone

appears to be homologous to the ancient nautiloid shell.

Extending anteriorly from the phragmocone in a dorsal position is the third component of the belemnite shell, the proostracum. Of the proostracum Jeletzky (1966) stated, "The neglected proostracum is a fundamental feature peculiar to coleoid cephalopods and represents a most important biological adaptation. (It) . . . is the only major comparable shell element common to both teuthoid and belemnite coleoids." The proostracal portion of the belemnite shell is the progenitor of the recent gladius (Jeletzky, 1966). Whether the belemnite shell was internal or external is not known.

The progressive reduction of the ancestral-type cephalopod shell was most probably due to increased predation pressure imposed by the onset of rapid vertebrate evolution. The heavy external nautiloid-type shells, which served as protection in the time when chambered cephalopods dominated the seas, were no longer an adequate defense against predatory fish and reptiles. Survival necessitated that armament be replaced by speed and agility (Dunbar, 1924). Shell reduction was compensated for by the development of the muscular mantle that provided for a change in the life history of the teuthoids to one of actively swimming, highly effective predators.

While exhibiting great morphological variation at the ordinal level, within each family the gladius of the recent teuthoids is largely a homogeneous structure showing more subtle morphological variation. In general, the gladius is a flattened, spatulate structure consisting of a narrow, thickened central axis called the rachis and thinner lateral expansions issuing from it called the wings or vanes. The rachis normally extends the entire length of the gladius while the vanes typically occupy only a portion of the total length. That part of the rachis that does not support vanes is called the free rachis. Reduction of the vanes is common in several groups. Also common is ventral flexion and fusion of the vanes along the ventral midline forming a hollow funnel or tube called the conus. Where ventral flexion brings the lateral margins of the vanes together without fusion taking place, the resulting structure is referred to as a 'pseudoconus' (McSweeney, 1978). In general, the gladii of the myopsids have broadly rounded vanes

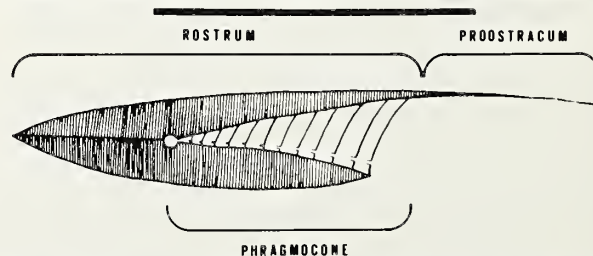


Figure 1. Longitudinal cross-section of belemnite shell showing major structural components (from Shrock and Twenhofel, 1953).

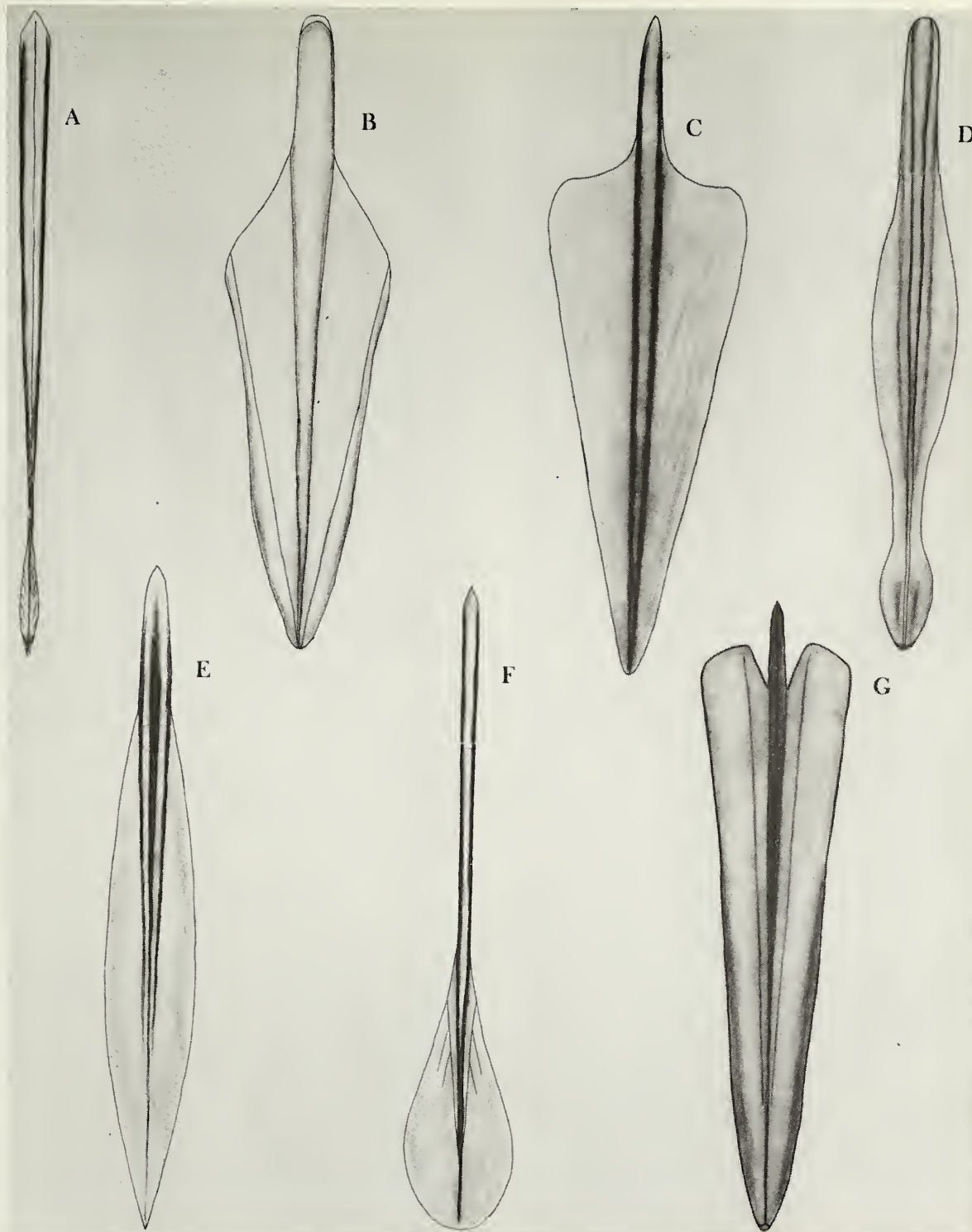


Figure 2. Representative gladii from several families of squids: a, Ommastrephidae (*Todarodes sagittatus*), redrawn from Pfeffer (1912); b, Enoploteuthidae (*Enoploteuthis anapsis*), redrawn from Roper (1966); c, Histioteuthidae (*Histioteuthis brunni*), redrawn from N. Voss (1969); d, Lycoteuthidae (*Lycoteuthis*

diadema), redrawn from G. Voss (1962); e, Loliginidae (*Loligo pealei*); f, Bathyteuthidae (*Bathyteuthis berryi*), redrawn from Roper (1969); g, Thysanoteuthidae (*Thysanoteuthis rhombus*), redrawn from Sasaski (1929). All gladii illustrated to same absolute size.

while those of the oegopsids display narrower, reduced vanes and a longer free rachis. A true conus is strictly an oegopsid feature (Figure 2).

The recent conus appears to be the evolutionary remains of the phragmocone and is therefore considered to be a vestigial structure. Additional vestigial structures exhibited in recent gladii bear evidence to support the evolutionary scheme mentioned earlier. Within the Onychoteuthidae, the gladii of *Onychoteuthis banksii* and *Moroteuthis longbergii* possess cartilagenous spines projecting dorsally from the posterior tip of the rachis (Sasaki, 1929). These spines may be homologous to the rostrum of the belemnite shell. Hoyle (1886) reported finding loose layers of chitin within the concavity of the conus of gonatid gladii. Resembling miniature watch glasses, these may be homologous to the septa of the ancient phragmocone. Such vestigial structures may reflect the phylogenetic antiquity of these groups.

The use of the gladius as a systematic character in the teuthoids has been emphasized to varying degrees by different authors. Many workers have examined the gladius and used it as a tool in systematics, as well as for phylogenetic considerations. Perhaps, no other worker has utilized this structure for both of these purposes more than Naef (1921/23), who constructed detailed evolutionary lineages based on gladius morphology. More recently, Voss (1962) postulated on the relationship between the Lycoteuthidae and Enoploteuthidae based on gladius morphology. Young and Roper (1969) suggested broad phylogenetic relationships among the families of oegopsids based on general gladius morphology and other characters. Numerous additional studies have indirectly pointed to the usefulness of the gladius for sub-familial identifications.

Investigations of functional morphology have demonstrated a variety of functions performed by the gladius. Most obviously, it lends support and rigidity to the mantle in numerous squid species. Many families of oegopsids possessing narrow elongated bodies show modifications of the gladius for strength. These include thickenings of the rachis and tubular-type construction imparted by extreme ventral flexion of the vanes. This is particularly noticeable in the Chiroteuthidae in which a cross section of the gladius resembles a structural beam. Within the myopsids, the loliginid genera *Alloteuthis* and *Uroteuthis* possess an extreme elongation of the posterior portion of the mantle, sometimes referred to as the 'tail.' The weak muscular investment of the tail is insufficient to support itself. In these groups, the gladius forms a pseudoconus to support this unusual modification. Such examples make it easy to understand why the gladius has come to be known as the 'pseudobackbone' of the squids.

Sexual dimorphic morphology of the gladius has been reported in several groups and appears to be especially common in the Loliginidae. One manifestation of this dimorphism is the width of the gladius: females possessing wider gladii with greater ventral curvature than males. In gravid females of several species, the enlarged ovary has been observed to lie within the curvature of the gladius. The additional width and curvature of the gladius appear to provide support and protection for the distended ovary until the time of spawning.

The gladius may also perform an ontogenic function in some species. McSweeney (1978) reported on a change in the swimming orientation of the cranchiid squid *Galiteuthis glacialis* during the course of its development. He postulated that this was caused by a change in the center of gravity which accompanied growth and elongation of the gladius. This phenomena is reminiscent of the counterweight theory of the belemnite rostrum.

In other squids, notably several members of the Cranchiidae,

the mantle has been sufficiently reduced or is of such a gelatinous consistency, so to no longer be able to serve as a site for fin insertion. In this case the gladius has taken over this function.

The gladius of *Thysanoteuthis rhombus* exhibits perhaps the most distinctive character of any teuthoid gladius (figure 2g). The anterior portion of the vanes are modified into free quadrangular lobes. These lobes have been found to encircle the nuchal area, providing additional support in this region and perhaps aiding in head-mantle aperture alignment during locomotor mantle contractions.

As is true of the shell of cephalopods throughout the course of evolution, the morphology of the gladius of recent squids reflects the various functional requirements placed upon it by the forces of adaptive evolutionary pressure.

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INVESTIGATIONS OF DECLINES IN FINGERNAIL CLAM (*MUSCULIUM TRANSVERSUM*) POPULATIONS IN THE ILLINOIS RIVER AND POOL 19 OF THE MISSISSIPPI RIVER

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INTRODUCTION

Certain sphaeriid clams are important components in the diets of many commercially important species of fish and many waterfowl in the Illinois River and the upper Mississippi River. During the mid-1950s, the fingernail clam, *Musculium transversum* (Say, 1829), died out from the middle 100-mile reach of the Illinois River (Paloumpis and Starrett, 1960; Anderson, 1977). The cause(s) of the disappearance is unknown and a recent survey of the bottom fauna of the Illinois River in 1975 revealed that the clams were still largely absent from this section of the river (Anderson, 1977).

Additionally, in 1976 and 1977 the numbers, biomass, and growth of fingernail clams in Pool 19, Mississippi River, sharply declined from 1973 levels (unpublished data, Illinois Natural History Survey). Pool 19 is a 74-km section of the Mississippi extending from Lock and Dam 18 near Burlington, Iowa downstream to Lock and Dam 19 at Keokuk, Iowa, and has been characterized as the most important inland body of water for diving ducks in North America (Trauger and Serie, 1974: 71). Peak numbers of the fingernail clam *Musculium transversum* in Pool 19 may exceed 100,000/m² (Gale, 1969) and may account for 85-95% by volume of the food items taken by certain diving ducks on the pool during spring migration (Thompson, 1973). This paper describes our efforts to isolate the factor(s) responsible for the declines of *M. transversum* populations in the Illinois River and Pool 19 of the Mississippi River.

MATERIALS AND METHODS

Two basic testing procedures have been employed in the present study. A rapid screening technique was developed which measures the effect of water quality factors on excised clam gills. Because lateral cilia on the gill of the clam produce the currents which bring food particles and oxygenated water into the clam and carry wastes away, any impairment of the activity of these cilia impairs the ability of the clam to respire and feed and would eventually affect the growth and survival of the clam. When the visceral ganglion, branchial nerve and gill are removed intact from the clam normal ciliary function is maintained for at least 5 days when the tissue is kept in standard physiological solution. Two of the water quality factors which have had the greatest effects on fingernail clam gills, un-ionized ammonia (the form of ammonia which is toxic to aquatic organisms) and Illinois River water, were selected for further testing using chronic addition and deletion bioassay methods.

Collection of Fingernail Clams

Fingernail clams were collected from Pool 19 of the Mississippi River using an 18-foot boat equipped with a crane and a Ponar grab sampler. The clams were separated from the mud by pressure-sieving the Ponar samples through 30-mesh screen with a 12-volt battery-operated water pump. The clams were carried to

the laboratory at Havana, Illinois in 37-liter plastic coolers half-filled with Mississippi River water and equipped with aerators.

Rapid Screening Procedure

Clams used in the rapid screening procedure at Southern Illinois University were transported from Havana by truck or shipped via parcel post. Clams used in the cilia monitoring apparatus were acclimated at least one week in invertebrate physiological solution.

The apparatus for monitoring ciliary activity of clam gills consists of two coupled microscopes and a scanning stage which holds two petri dishes, each containing a gill preparation. A continuous flow of standard physiological solution or solution to which test chemicals have been added can be maintained across the petri dishes by means of metering pumps. A calibrated stroboscopic light serves as a substage light source for both microscopes. The rate of ciliary beating of lateral cilia (in beats per second) is measured by synchronizing the rate of the light with the rate of the lateral cilia. A more complete description of the rapid screening procedure and apparatus may be found in Anderson, Sparks, and Paparo (1978).

Chronic Addition Bioassay Procedure

A modified proportional diluter (Mount and Brungs, 1967) was used to deliver a logarithmic series of test solutions to five aquaria and unchlorinated well water to a control. A feeding system was incorporated into the proportional diluter to deliver a measured amount of food every dilution cycle. The food suspension was prepared as suggested by Biesinger and Christensen (1972).

Clams were acclimated following recommendations by the Committee on Methods for Toxicity Tests with Aquatic Organisms (1975). In the chronic tests, 20 clams were used per petri dish with two petri dishes in each test aquarium. Growth was determined by measuring the maximum length of the shell to the nearest 0.1 mm with an ocular micrometer. Survival and growth of the clams was checked once every two weeks.

Data from the chronic bioassays were used to determine maximum acceptable toxicant concentrations (MATC) as suggested by the American Public Health Association (1976). MATC's were computed for both mortality and growth. Replicate mortalities and pooled clam lengths in each test aquarium were subjected to analysis of variance, ANOVA (Steel and Torrie, 1960). When treatment effects were indicated by ANOVA, the means of these effects were subjected to the Newman-Kuel's multiple-range test (Steel and Torrie, 1960). Data collected from test chambers showing mortalities significantly higher than the controls were not used in the analysis of clam lengths.

Chronic Deletion Bioassay Procedures

A deletion bioassay apparatus presently is being used to expose fingernail clams to four test conditions and a control group to unchlorinated well water. In this design the mixture of raw Illinois River water and sediment is subjected to the following treatments: (1) sand filtration to remove sediment, (2) sand filtration plus charcoal filtration to remove organic chemicals, and (3) sand filtration plus clinoptilolite resin filtration to remove ammonia (Figure 1). The remaining test condition exposes clams to untreated Illinois River water and sediment (Figure 1).

The clams are fed 50 ml of concentrated *Ankistrodesmus falcatus* (Chlorophyta) algal solution twice a day from a pipette. The acclimation and test procedures otherwise were the same as for the addition bioassays.

EXPERIMENTAL DESIGN: DELETION BIOASSAYS

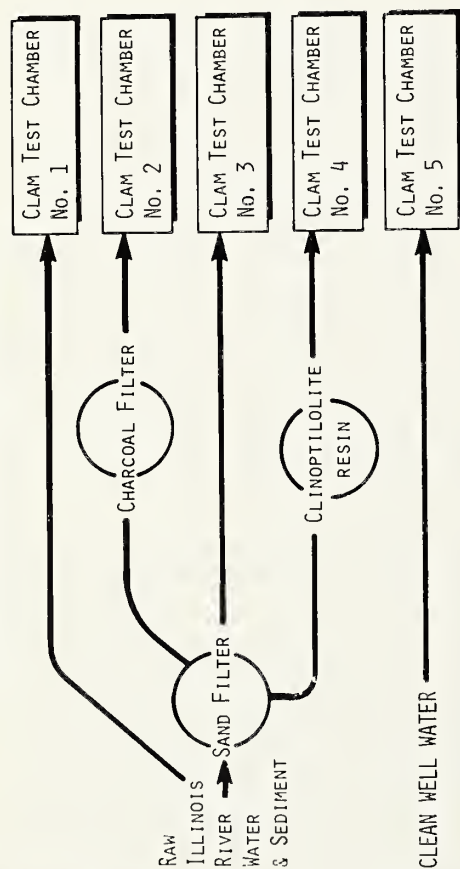


Figure 1

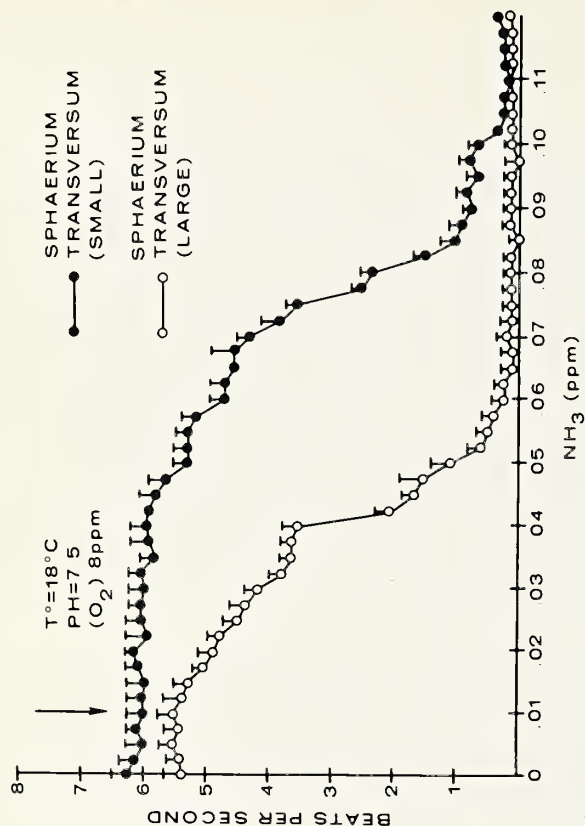


Figure 2

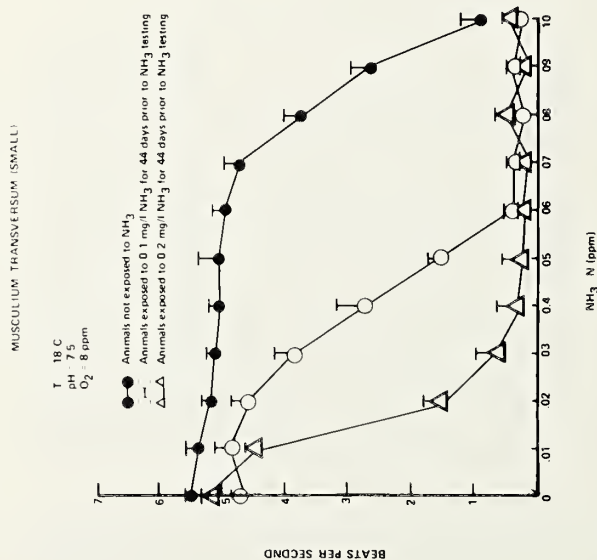


Figure 3

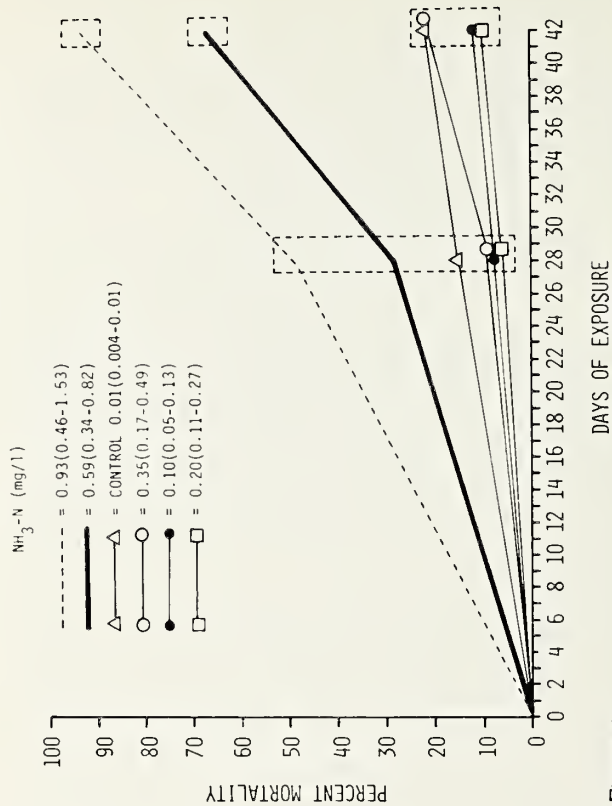


Figure 4

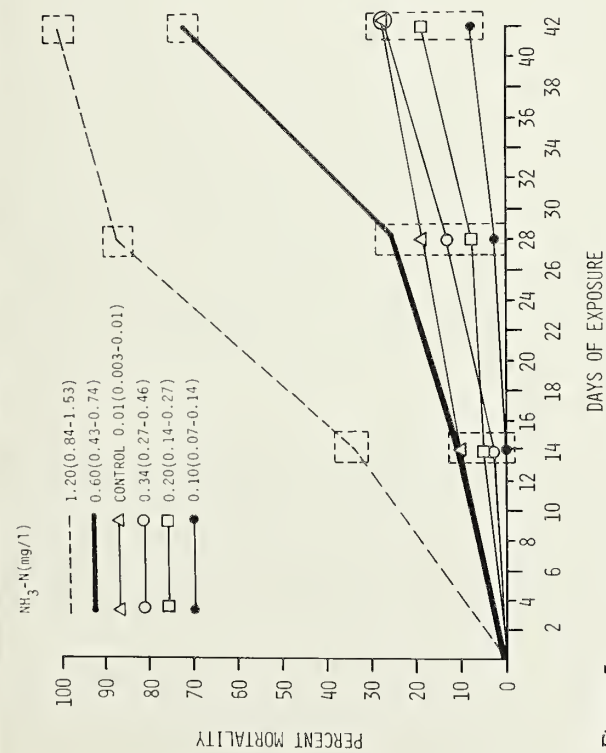


Figure 5

$\text{NH}_3(\text{u})\text{-N}$ CONCENTRATIONS IN KEOKUK POOL,
MISSISSIPPI RIVER, JULY-DECEMBER 1973 & 1976
WEEKLY MAXIMUM VALUES CALCULATED FROM TOTAL $\text{NH}_3\text{-N}$
DATA PROVIDED BY CHEVRON (ORTHO) CHEMICAL CO.,
FORT MADISON, IOWA (24-HOUR COMPOSITE
INTAKE SAMPLES)

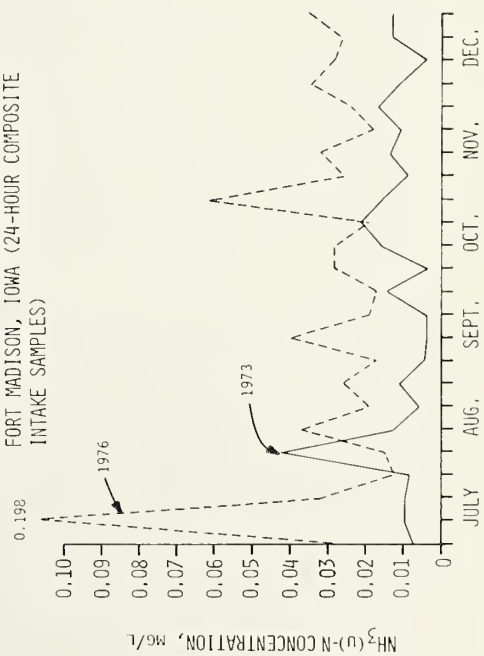


Figure 7

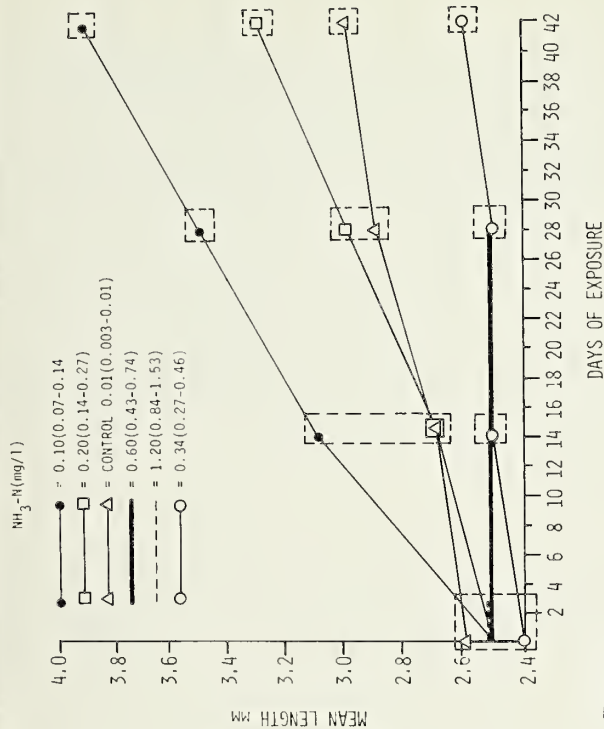


Figure 6

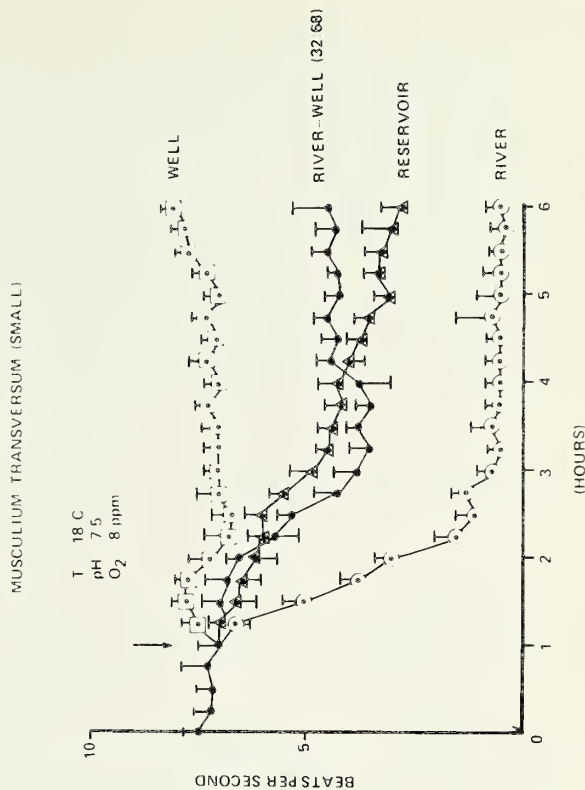


Figure 8

Figure 1. Chronic deletion bioassay system.

Figure 2. Ciliary beating response of gills from large and small fingernail clams to un-ionized ammonia (expressed as NH_3 , ppm, or mg/l) and $\text{NH}_3\text{-N}$ concentrations ($\text{NH}_3 \times 0.824$) which induced various degrees of inhibition of ciliary activity of gills from *M. transversum*.

Figure 3. When clams are exposed to sublethal concentrations of un-ionized ammonia (0.1 and 0.2 mg/l $\text{NH}_3\text{-N}$) for 44 days, then gills are sensitized to subsequent additions of ammonia.

Figure 4. Un-ionized ammonia concentrations of 0.93 and 0.59 mg/l (as $\text{NH}_3\text{-N}$) caused significant ($p < 0.05$) mortality among fingernail clams after 42 days of exposure. All points within the same box are not significantly different ($p > 0.05$).

Figure 5. An un-ionized ammonia concentration of 1.20 mg/l caused significant ($p < 0.05$) mortality among fingernail clams after 14 days of exposure, and a concentration of 0.60 mg/l

caused significant mortalities after 42 days. Mortalities at the other concentrations were not significantly different from controls.

Figure 6. Un-ionized ammonia concentrations of 0.34 and 0.60 mg/l ($\text{NH}_3\text{-N}$) significantly ($p < 0.05$) reduced the growth of fingernail clams after 14 days of exposure.

Figure 7. The concentration of un-ionized ammonia ($\text{NH}_3\text{-N}$) in Pool 19, Mississippi River, was greater in 1976 than in 1973.

Figure 8. The ciliary activity of gills from small fingernail clams was almost completely inhibited when the gills were exposed to Illinois River water. Normal ciliary activity was maintained in well water while an intermediate response occurred in river water diluted with well water. No additional effect was obtained after the diluted water was stored several days in an aluminum-painted steel reservoir.

The statistical methods for the deletion tests follow those of the addition bioassay with the exception of the MATC determinations which are not applicable.

RESULTS AND DISCUSSION

Rapid Screening Procedure – Un-ionized NH_3

While the rapid screening method has been employed to test a wide range of parameters to date, only two of these tests, with un-ionized $\text{NH}_3\text{-N}$ and untreated Illinois River water, will be discussed here. Figure 2 demonstrates the sensitivity of *M. transversum* to low levels of un-ionized ammonia (measured as NH_3). The un-ionized ammonia values shown in Figure 2 have been converted to un-ionized ammonia nitrogen ($\text{NH}_3\text{-N}$), by multiplying by 0.824 to show the concentrations of $\text{NH}_3\text{-N}$ which induced various degrees of inhibition of ciliary activity. Toxic ammonia values are most commonly expressed as $\text{NH}_3\text{-N}$. Note the greater sensitivity of large (≥ 5 mm), reproductive sized clams versus small (< 5 mm) clams as a 90% reduction of ciliary activity is achieved in gills from large clams with one-half (0.4 mg/l) the amount of un-ionized ammonia ($\text{NH}_3\text{-N}$) which achieves a 90% reduction (0.8 mg/l) in gills from small clams (Figure 2). Clams previously exposed to sublethal concentrations of un-ionized ammonia are sensitized to subsequent additions of ammonia (Figure 3).

Chronic Addition Bioassays – Un-ionized $\text{NH}_3\text{-N}$

Because the results of rapid screening tests demonstrated the sensitivity of excised clam gills to un-ionized ammonia, two chronic addition bioassays using un-ionized ammonia ($\text{NH}_3\text{-N}$) as the toxicant were performed on intact, juvenile (< 5 mm) clams. The fingernail clams in the first bioassay exhibited significant mortalities in the upper two concentrations of 0.59 and 0.93 mg/l un-ionized ammonia after 42 days of continuous exposure to ammonia (Figure 4). The resulting MATC, based on mortality, is between 0.35 and 0.59 mg/l un-ionized $\text{NH}_3\text{-N}$.

A second ammonia bioassay was performed to obtain adequate growth data in order to estimate the MATC for growth. The results of this test, based on mortality, confirmed the results of the first bioassay, demonstrating a MATC for mortality of 0.34-0.60 mg/l $\text{NH}_3\text{-N}$ (Figure 5). Results of the second test show that

un-ionized ammonia concentrations of 0.34 and 0.60 mg/l $\text{NH}_3\text{-N}$ significantly reduced the growth of clams after 14 days of exposure (Figure 6). The resulting MATC, for growth, lies between 0.20 and 0.34 mg/l $\text{NH}_3\text{-N}$. While the control group did not exhibit the fastest growth rate, the other test groups did exhibit a pattern of reduced growth with increasing ammonia concentration which suggests that ammonia inhibits clam growth. In addition, the NH_3 delivered to the test aquaria stimulates the growth of bacteria which the clams feed upon.

The results of the rapid screening tests and the chronic addition bioassays for un-ionized ammonia point to the sensitivity of both excised gills from fingernail clams and intact *M. transversum*. Figure 7 shows that the levels of ammonia found in the pool in July, 1976 (0.198 mg/l) approach the value of 0.34 mg/l $\text{NH}_3\text{-N}$ which significantly reduced the growth of fingernail clams during addition bioassays (Figure 6). A slight increase in ammonia levels in the pool in 1976 would have raised ammonia concentrations within the range which impaired clam growth in the laboratory. In addition, the levels of ammonia in Pool 19 during 1976 approached or exceeded the levels of $\text{NH}_3\text{-N}$ which significantly reduced the ciliary beating rate of gills from large (reproductively-sized) clams (Figure 2). It should be noted, however, that the values expressed in Figure 7 represent a single location in Pool 19 and that the elevated ammonia values may have resulted from the low flow in the Mississippi River in 1976 and the spring of 1977.

Rapid Screening Procedure – Illinois River Water

The beating of cilia on gills from small fingernail clams was almost completely inhibited after the gills were exposed to water taken from the Illinois River on October 5, 1977 (Figure 8). Clam gills exposed to the same well water pumped to control aquaria during chronic tests maintained normal ciliary activity, while gills exposed to a mixture of Illinois River water and well water exhibited partial inhibition (Figure 8).

Chronic Deletion Bioassay – Illinois River Water

The deletion bioassay apparatus described in this paper is currently being used to determine the effects of the various treatments of Illinois River water on fingernail clam survival, growth and reproduction.

CONCLUSIONS

To conclude, a rapid screening method using isolated *Musculium transversum* gills and chronic bioassays with intact clams both show that the clams are sensitive to low concentrations of ammonia. Elevated concentrations of ammonia may have played a role in, but have not been the sole cause of, declines in fingernail clam populations in Pool 19 of the Mississippi during 1976-77. The rapid screening method also demonstrated that Illinois River water inhibits the ciliary activity of fingernail clams and tests now in progress should show whether deletion of certain components of Illinois River water, including ammonia, will permit clams to survive, grow, and reproduce.

ACKNOWLEDGEMENTS

We are grateful to the Division of Fisheries, Illinois Department of Conservation for providing laboratory space for the project. The initial phase of the project was supported by the Department of the Interior and administered by the University of Illinois, Water Resources Center, Agreement No. USDI 14-31-0001-6072. The project is currently supported by the Department of Commerce, National Marine Fisheries Service, and the Department of the Interior, administered respectively by the Illinois Department of Conservation, Division of Fisheries, Agreement No. 1-47-26-82-361, and the University of Illinois, Water Resources Center, Agreement No. USDI 14-34-0001-9069.

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MOLLUSCAN RESPONSE TO
ORGANOTIN ANTIFOULANTS

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Marine fouling is the attachment of marine organisms, such as algae and barnacles to a surface immersed in sea water. This fouling is a well known, worldwide problem which results in significant economic loss due to structural damage and increased fuel consumption by marine vessels (Starbird and Sisson 1973). Considering the sharp and continued rise in energy costs, fouling becomes an important economic factor. Any attempt at fuel economy in the Navy or the shipping industry must have as its first priority the development of effective antifoulant procedures.

The most realistic method of dealing with this fouling problem is the use of paint formulations containing toxic components. These paints function by slow release of chemicals which are poisonous to marine organisms thus preventing their attachment to a vessel's hull (Monaghan, Kulkarni and Good, 1978 a, b). The most widely used toxicant has been cuprous oxide but various organometallic compounds of arsenic, mercury, lead and tin

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have been used. The arsenic, mercury and lead coatings have severe toxicological effects on vertebrates and have been either restricted in use or completely removed from the commercial market.

Studies have indicated that organotin antifoulants show particular promise since they exhibit control over a variety of fouling organisms for relatively long periods of time and the organotins do not promote corrosion when applied over conductive substrates as do copper-based coatings. At the present time, organotin compounds are increasing in commercial use in many antifouling systems (Evans and Smith, 1975). Due to the slow release, or leaching, from the coated hulls of marine vessels, these toxicants could rapidly be dispersed in all marine waters. Current research at the University of New Orleans and Louisiana State University is concentrated on determining accurate leach rates and leaching mechanisms for the organotins. Once the research is completed predictions can be made of the quantity and forms of organotin that will be released into the marine environment, and the resulting environmental impact from these antifouling toxicants.

The bioassay phase of our research, described here is directed at investigating the effect of these organotins on non-fouling organisms in the environment, and determining the environmental fate of these compounds and their degradation products.

We constructed a portable bio-assay laboratory from a 17' travel trailer. This allowed for the location of the experiments such that habitat water and test organisms were easily available. The

trailer was modified to hold a series of all-glass test aquaria stock tanks and various pieces of equipment for handling the organotin compounds. Each test aquarium was aerated by use of an air compressor and gas diffusion tube. Half of the experimental tanks contained 1 liter of substrate the other half did not. The substrate was collected from two sites on the lake. One site had a sandy substrate; the other a rich, organic mud-silt mixture. The total volume of habitat water in each tank was 4 liters.

The trailer was positioned on the south shore of Lake Pontchartrain, a large estuary just north of New Orleans, Louisiana.

The organisms tested were of a brackish water clam, *Rangia cuneata*, which is abundant in Lake Pontchartrain; the bent mussel, *Ischadium recurvum*; and various fish species including *Gambusia affinis*, *Poecilia latipinna*, *Fundulus grandis* and *Cyprinodon variegatus*. A mixture of the fishes was used due to insufficient numbers of any one species being available when needed.

A series of experiments was designed to test liquid organotin compounds, namely tributyltin acetate (TBT AC) and triphenyltin acetate (TPT AC). These compounds were dissolved in habitat water and a series of known concentrations from 1.00 ppm to 0.02 ppm was established. The exposure time varied from 20 min. at 1.00 ppm to three days at 0.02 ppm. The fish died at all concentrations. It appeared that the tributyltin and triphenyltin compounds were equally toxic.

There was a significant difference between the fish response and the molluscan response to the organotins. Concentrations of tributyltin acetate (TBT AC) above 0.10 ppm were toxic to all *Rangia cuneata* tested with exposure time varying from 4 days at 1.00 ppm to 12 days at 0.20 ppm. A concentration of 0.10 ppm appears to be the lethal dosage (LD₁₀₀) of TBT AC. Concentrations higher than 0.10 ppm were lethal to all *Rangia cuneata* tested, but concentrations lower than 0.10 ppm were not lethal during the long testing periods. Triphenyltin acetate (TPT AC) exhibited a slightly higher degree of toxicity to the clams with deaths occurring at a lower concentration (0.05 ppm). The lowest concentration of triphenyltin acetate that is lethal to the clams, the threshold concentration, has yet to be determined.

Juvenile *Rangia cuneata* were also used and all concentrations of TBT AC and TPT AC tested (0.10 ppm to 0.02 ppm) proved lethal to the clams. An approximate ten-fold increase in toxicity was seen in the juvenile clams compared to the adult clams. No threshold concentration has yet been determined for juvenile *Rangia cuneata*.

After the liquid tests were completed, experiments using panels painted with various organotin compounds were done. The panels are 8 x 8 cm aluminum squares prepared with a primer coat, two paint layers, and an outer layer of paint containing the various organotin toxicants. This panel preparation is similar to the anti-fouling preparation of ship hulls. Five different compounds were tested: Triphenyltin acetate, (TPT AC), triphenyltin hydroxide (TPT OH), triphenyltin fluoride (TPT F), triphenyltin chloride (TPT Cl), and triphenyltin oxide (TPT O). The results after a 42 day test showed no deaths in the TPT F, TPT Cl, or TPT O. But all clams, mussels, and fish died within 22 days in the TPT AC and TPT OH.

Throughout the liquid and panel tests distress symptoms of the test organisms were noted. The fish exhibited erratic swimming movements, loss of equilibrium, convulsions, loss of buoyancy and in some cases severe bleeding from the gills.

The clam and mussel distress symptoms were noted as progressing from a slight gaping with the siphons withdrawn into the shell, to a release of excess mucus which clouded the water, then

a swelling of the siphons and mantle edges, insensitivity to touch, and finally death. We had also found that these distress symptoms could be reversed by moving the exposed clams and mussels from the test tanks and placing them in clean tanks with fresh habitat water. Most of the exposed clams and mussels recovered within 10 days, regaining the normal sensitivity of the siphons and mantle edges.

Throughout these experiments organisms appeared to survive longer in tanks containing substrate; particularly tanks containing the rich organic mud substrate. An experiment was designed which allowed a known concentration of organotin to stand for 19 days in two separate tanks. Each tank contained 1 liter of either a sand substrate or the rich organic mud substrate. Water was drawn off from each tank in two portions; one portion was filtered and the other was not. The results of this test showed that no deaths occurred in the tanks using the filtered and non-filtered water from the rich-organic mud substrate and all organisms appeared healthy. But most of the test organisms in the filtered and non-filtered tanks from the sand substrate died within 20 days. Three fish died in the filtered sand tank, 2 fish survived, 5 clams survived but appeared distressed. The non-filtered sand tank had 4 fish deaths, 4 clam deaths: 1 fish and 1 clam survived but also appeared distressed. This experiment gave support to the assumption that organotin compounds are, in some way, taken up by organic soil substrates.

When the Lake Pontchartrain experiments were completed we moved our lab to Point Cadet in Biloxi, Mississippi. There we worked on the effects of these coatings on the American oyster, *Crassostrea virginica*; the green nerite, *Neritina reclinata*; and the bent mussel, *Ischadium recurvum*. We also tested various fish and marine crustaceans. The fish tested included the Atlantic croaker, *Micropogon undulatus*; sea catfish, *Arius felis*; bay anchovy, *Anchoa mitchilli*; and striped mullet, *Mugil cephalus*. Crustaceans tested were: blue crabs, *Callinectes sapidus*; hermit crabs, *Clibanarius bivittatus*; grass shrimp, *Paleomonetes pugio*; white shrimp, *Penaeus setiferus*; brown shrimp, *Penaeus aztecus*; and to a limited extent the barnacle, *Balanus improvisus*.

Tests thus far have shown toxic effects in the fishes similar to those already described and it appears that the kill rate is independent of fish size.

The marine crustaceans tested appear less sensitive to the organotins than fish and molluscs, and they show a wider variance in response to the organotin compounds. Barnacles, white shrimp, and brown shrimp are more sensitive to the organotins than the grass shrimp, hermit crabs, and blue crabs.

Oysters show a response similar to the clams and mussels previously tested; distress symptoms appear as: an excess of mucus released, shell gaping, and insensitivity to touch. The shell edge of some of the test oysters was filed so that the oyster would be constantly exposed to the toxicants. In the control tanks and in test tanks of relatively low concentration (about 0.04 ppm of TBT AC) the shells were completely rebuilt after about 8 days. In concentrations above 0.06 ppm of TBT AC no rebuilding of the shell was seen and a greater amount of mucus was noted in the water.

The *Neritina* showed again the same insensitivity to touch, slow reaction, and the release of mucus. In some cases the snails responded to the antifouling compounds by completely covering the aperture of the shell with a white mucus coating.

Research is continuing with plans to locate, in the environment, panels prepared with various organotin compounds. This phase of research will give us fouling data which can be correlated with our previous results.

In a relatively short period of time the use of organotin compounds has increased significantly and indications are that such an increase will continue. In view of our findings concerning the lethal effects of even very small quantities of these antifoulants, we can clearly see the need for determining the long-term environmental effects of organotin compounds. Studies are continuing during which we will investigate the mode and rate of degradation of these organotin toxicants, the histological and cytological effects of the organotins on the organisms, and the effectiveness of substrate in removing the organotin compounds.

Our studies thus far have demonstrated that extreme caution in the use of these organotin antifoulants is mandated until such time as we have better understanding of the environmental consequences of their use.

DISPERSAL MECHANISMS IN SPHAERIIDAE (MOLLUSCA: BIVALVIA)

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INTRODUCTION

Most authors (Kew 1893; Boycott 1936; Baker 1945; Malone 1965 a, b, 1966; Rees 1965) agree that birds, especially shorebirds and waterfowl, are primarily responsible for transporting mollusks overland to isolated bodies of water. Snails attach to the feet and feathers of birds and once removed from water, retain their viability for sufficient lengths of time to effect overland dispersal for great distances (Malone 1965a). Insects appear to be effective dispersal agents of small snails and clams over short distances (Rees 1965).

External transport (e.g. on feet and feathers) of snails appears to be a more effective dispersal mechanism than internal transport via the digestive tract. Dispersal via the crop involves short distances but is probably more significant than via the intestinal tract since few snails remain viable in the excreta after two hours (Malone 1965b).

Although there are numerous records of sphaeriids found attached to the extremities of insects and birds (see Rees 1965) and they form a major portion of the diet in waterfowl (Cottam 1939; Anderson 1959; Rogers & Korschgen 1966; Dirschl 1969; Thompson 1973), the viability of sphaeriids after external or internal transport has never been shown. The purpose of the present study was to determine the viability of different age classes of six common species of sphaeriids in rivers and isolated ponds after feeding to mallards, *Anas platyrhynchos platyrhynchos*, and after various periods of desiccation at different humidities with closed valves and in the air with gaping valves.

MATERIALS AND METHODS

Eight populations of six species of sphaeriids, all near Guelph, Ontario, were used in this study: *Sphaerium fabale* from the Eramosa River; *Sphaerium occidentale* and *Musculium securis* from a temporary pond on Clair Road; *Musculium lacustre* from permanent ponds in Kortright Waterfowl Reserve; *Pisidium casertanum* from a temporary pool off Hanlon Creek and a temporary roadside pond on Wellington Road 32. Collections of 30-300

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clams from each population were made usually at least twice a month from May to October, 1975, using a sieve with 0.32 mm openings. Details of habitat characteristics and of the life histories of all populations are given in Mackie (1979), McKee & Mackie (1979), and McKee (1979).

To determine the viability of different length classes of sphaeriids, after internal transport in birds, all clams in each collection were measured for length and then fed to one of eight mallard ducks. The ducks were kept in two cages, each about 1.5 m high, 1.5 m wide, 3.0 m long and 0.5 m above the ground. Each cage was divided in half by a screen with one pair of males in one end of the cage and one pair of females in the other. The cages consisted of a tubular steel frame wrapped with ½ in. (13 mm) square, heavy gauge, steel mesh on all six sides. The roof and most of the sides of the cages were covered with burlap to provide shade for the ducks. Sixteen galvanized trays, each 0.4 m wide, 0.8 m long, 7.5 cm deep, and covered with dark green plastic bags were filled with water and placed under each cage to catch excreta and regurgitated food from the ducks. Since the ducks often "spit out" the large clams before swallowing, the clams were mixed with moistened grain and oats. The time of feeding, number of clams in each 0.50 mm length class interval, the sex of duck that regurgitated or defecated, and the time of regurgitation or defecation were noted. Any clams that appeared in the excreta and regurgitated material were isolated into glass dishes (100 mm diam, 50 mm ht) and grown on willow leaves and soil according to techniques described by Mackie and Qadri (1978). The clams were allowed to grow until they died or produced one litter of newborn, whichever occurred first.

To determine the resistance of clams to desiccation during transport on the extremities of dispersal agents, 10 adults and 10 newborn of each species were suspended in the air with the end of a 15-cm long x 0.20-mm diameter copper wire clamped between the valves for 15 min. Two other groups of 10 individuals in each age class were suspended for 30 and 60 min. At the end of each time period, the clams were put back into small dishes with water and were considered viable if they began to crawl. Also, experiments were carried out to determine the resistance of four species of clams, *S. fabale*, *S. occidentale*, *M. securis*, and *P. casertanum*, to desiccation at different humidities. Four graded solutions of NaOH were prepared by the method of Madge (1961) to provide atmospheres of 20, 40, 60 and 80% relative humidities at 20°C. Five, 4-L plastic buckets with flat-surfaced

rims were used to contain 20 newborn and 20 part-grown clams each of *M. securis*, *P. casertanum* and *S. fabale* and 20 estivating and 20 active clams of *S. occidentale*, and 300 ml of the NaOH solutions. Porcelain discs (15 cm diam) with seven, 3-cm diam holes each with nylon mesh glued to the bottom, were used to hold the clams above the solutions. The buckets were tightly sealed by 23-cm square sheets of glass using a layer of grease on the rims. Observations on survival were made frequently at first (several times during the first 24 hr) and weekly after the first 12 days up to 48 days for *M. securis* and *S. occidentale* and up to 21 days for *S. fabale* and *P. casertanum*. To separate the effects of starvation and desiccation a control of 10 clams of each species in frequently-changed filtered pond water was monitored in each experiment. Death of clams was determined by the apparent arrest of the heart beat in *M. securis* and by the collapse of the gills against the shell in the other three species, as recommended by McKee (1979).

RESULTS

Of 308 *S. occidentale*, 202 *S. fabale*, 794 *M. lacustre*, 1933 *M. securis*, 850 *P. casertanum*, and 165 *P. variable* fed to mallards, none were found in the excreta and only 2 *M. securis* and 2 *S. occidentale* were found in regurgitated material in the trays below the bird cages. The 2 *M. securis* were of newborn size but they must have been fed to the ducks as extra-marsupial larvae (a late larval stage brooded by parent clams) since newborn were not present in the samples fed to the ducks. The two *S. occidentale* clams retrieved also were of nepionic size but it is not known whether they were fed to ducks as newborn or as extra-marsupial larvae, since both were present in the samples fed to the ducks in that particular feeding experiment. Only three of the four clams (1 *M. securis* died) retrieved in the trays grew and reproduced in laboratory cultures with mean brood sizes of 2.0 in *M. securis* and 2.5 in *S. occidentale* in their first litters.

Table 1 shows that mortality of clams attached to wires increased with time and that few clams survived for 60 min. Adults appeared to be more viable than newborn in *S. occidentale* and in both species of *Musculium* but equally viable in *S. fabale* and *Psidium* spp. All clams that died had a large air bubble in the mantle cavity that prevented them from submerging. The most viable life history stage was the extra-marsupial larva since more than 50% of those present were still viable in parents, living or dead, after 1 hr (Table 2). Figs. 1a-d, show that the viability of clams increased with increasing humidity. Estivating *S. occidentale* (Fig. 1b) were much more resistant to desiccation than active individuals from the flooded pond. Newborn *S. fabale* (Fig. 1a) and *M. securis* (Fig. 1c) were less resistant to desiccation than adults at low humidities but only newborn survived more than 80 hrs in 100% humidity. Both newborn and adult *P. casertanum* appeared to be equally viable, but viability was still a function of humidity (Fig. 1d).

DISCUSSION

As with gastropods (Malone 1965b), it seems unlikely that dispersal of Sphaeriidae via the intestinal tract of birds is of much consequence. The only significant aspect of internal transport is the transport of clams in the bird's crop. Although contents of the crop are acidic (pH about 4.9), little digestion apparently occurs here, most of the digestion occurring in the proventriculus and gizzard where pHs drop to 3.4 and 2.3, respectively (Famer 1942). Thus if sphaeriids contained in the crop were regurgitated,

the present study indicates that some would be viable, especially the extra-marsupial larvae which are protected by the parent's shell. Although only 4 out of 4252 (= 0.1%) were viable after being swallowed, the growth studies indicate that only one clam is required to begin a population since they are hermaphroditic and capable of self-fertilization. Also, if the life history of the clams are such that the most viable stage (i.e. extra-marsupial) is present during the migratory periods of the ducks, the chances of dispersal are correspondingly increased. Indeed, if only gravid parents (i.e. carry shelled-larvae) are considered (i.e. 204 instead of 4252) and assuming only one extra-marsupial larva per parent, the percent viability increases twenty-fold, to 2.0%. In fact one parent may carry up to 8 extra-marsupial larvae (Mackie 1979) and if all are viable, viability increases to 16% and the probability for internal transport by waterfowl becomes highly significant.

The life history studies on these same populations of sphaeriids by Mackie (1979) indicate that extra-marsupial larvae of all species are present during the migratory periods (i.e. spring and fall) of most ducks. Hence there appears to be selective advantage for clams to reproduce during the spring and (or) fall. For species that occur in isolated, temporary ponds (e.g. *S. occidentale* and all species of *Musculium*), it is especially important to have extra-marsupial larvae present in the spring before the ponds dry and when the ducks can feed. The probability of such habitats being visited by ducks increases during breeding seasons since ducks appear to select animal foods high in protein and calcium for egg production at this time (Krapu & Swanson 1975). The distance that clams are dispersed via the crop depends on when the birds regurgitate. The present study indicates that although the mallards regurgitated food up to 45 minutes after ingestion, the viable clams were regurgitated only 15 minutes later indicating a short range dispersal mechanism.

External transport also appears to be a significant dispersal mechanism for Sphaeriidae. There are two methods by which sphaeriids may become lodged externally on birds; (1) clams may attach themselves by clamping feathers or other extremities between their valves or (2) clams may become lodged among feathers when birds dabble and stir up the bottom. In the first method, the thickness of the extremity will limit the distance that sphaeriids can be dispersed. The data indicate that when the valves gape, air enters the mantle cavity and the greater the valves gape, the sooner the clams perish. It is not known whether the clams perish because the air bubble kills them directly or because the air bubble prevents them from submerging. The data also suggest that clams with gaping valves will survive longer in higher than in lower humidities and the tighter the valves close, the greater the chance of survival over long distances.

The desiccation experiments also suggest that the most viable life history stage is the extra-marsupial larva and the most probable dispersal period occurs when ducks are active in ponds when this stage is present. *Sphaerium occidentale* is particularly resistant to desiccation when it is preparing for estivation. However, this occurs just before the ponds dry and after they have burrowed into the sediments (McKee 1979) so it is not likely that they are dispersed by ducks during the estivation stage.

Insects also appear to be effective dispersal agents of sphaeriids. Several species of sphaeriids have been reported on the legs of aquatic beetles in flight and swimming (see Rees 1965). During the present study, *M. lacustre* was found clamped onto the tarsal claws of a dragonfly nymph (Fig. 2). Swimming insects serve only to disperse clams within a body of water while large insects capable of flight (e.g. *Dytiscus* sp., *Lethocerus* sp., *Belostoma* sp.) may play a major role in dispersing clams up to 8 miles (Rees

Table 1. NUMBER OF CLAMS VIABLE (OUT OF 10) IN TWO AGE CLASSES OF SIX SPECIES OF SPHAERIIDAE AFTER 15, 30, AND 60 MIN SUSPENSION IN AIR WITH A 0.20 MM DIAM WIRE CLAMPED BETWEEN THE VALVES. NB = NEWBORN, AD = ADULTS.

TIME SUSPENDED (MIN)	SPECIES											
	<i>Sphaerium fabale</i>		<i>Sphaerium occidentale</i>		<i>Musculium lacustre</i>		<i>Musculium securis</i>		<i>Pisidium casertanum</i>		<i>Pisidium variable</i>	
	NB	AD	NB	AD	NB	AD	NB	AD	NB	AD	NB	AD
15	4	4	8	8	7	5	8	4	6	6	6	6
30	4	5	3	6	2	5	2	5	3	5	3	3
60	0	0	0	1	0	1	0	0	0	1	0	0

Table 2. PERCENTAGE OF EXTRA-MARSUPIAL LARVAE VIABLE IN PARENTS OF SIX SPECIES OF SPHAERIIDAE AFTER 15, 30 AND 60 MIN SUSPENSION IN THE AIR WITH A 0.20 MM DIAM WIRE CLAMPED BETWEEN THE PARENT'S VALVES. THE FIRST COLUMN UNDER EACH SPECIES SHOWS THE NUMBER OF PARENTS (OUT OF 10) THAT CONTAINED EXTRA-MARSUPIAL LARVAE (EM).

TIME SUSPENDED (MIN)	SPECIES											
	<i>Sphaerium fabale</i>		<i>Sphaerium occidentale</i>		<i>Musculium lacustre</i>		<i>Musculium securis</i>		<i>Pisidium casertanum</i>		<i>Pisidium variable</i>	
	No. with EM	% EM viable	No. with EM	% EM viable	No. with EM	% EM viable	No. with EM	% EM viable	No. with EM	% EM viable	No. with EM	% EM viable
15	4	100	3	100	8	100	10	100	5	100	3	85
30	2	85	2	100	10	85	10	85	6	100	5	100
60	3	50	2	85	6	60	10	100	4	100	2	50

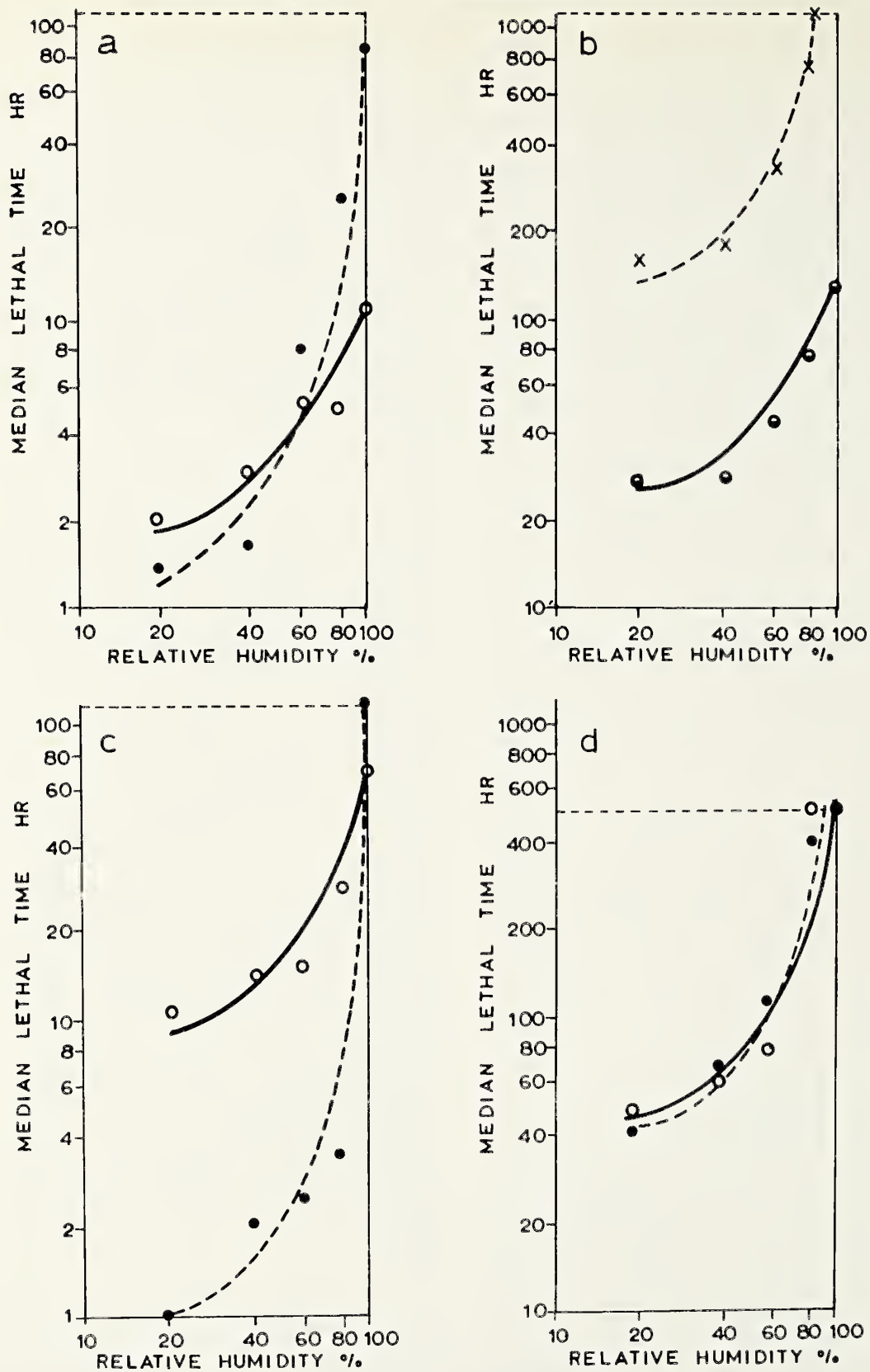


Fig. 1. Mortality curves for (a) *Sphaerium fabale*, (b) *Sphaerium occidentale*, (c) *Musculium securis*, and (d) *Pisidium casertanum* in atmospheres of 20, 40, 60, 80, and 100% (water only) relative humidity at 20°C. Open circles are adults, closed circles are newborn, half-closed circles are mixtures of adults and newborn from flooded pond, x's are estimating newborn and adults from dried pond.



Fig. 2. Dragonfly nymph with 2 *Musculium lacustre* clams clamped to tarsal claws.

1965). Other dispersal agents of Sphaeriidae may include aquatic mammals (e.g. beavers, muskrat, otters) and fish. Additional studies are needed to assess the role of mammals in dispersal overland and of fish in dispersal within a watershed.

In summary, the ability to be passively transported and the capability for facultative self-fertilization are interdependent features which enable Sphaeriidae to colonize rapidly previously unoccupied geographical areas (Clarke 1969). The ovoviparous habit and the production of a viable larval stage (extra-marsupial) during the feeding, breeding and migratory periods of waterfowl appear to be additional adaptive characters in Sphaeriidae that contribute to their cosmopolitan distribution.

ACKNOWLEDGEMENTS

The author is especially grateful to Mr. Jim Allen for carrying out all the feeding experiments. Mr. Paul McKee kindly permitted use of his desiccation data on *S. occidentale* and *M. securis*. The mallard ducks and holding cages were provided by the Kortright Waterfowl Foundation. The study was supported by a grant awarded to the author by the NRCC (No. A-9882).

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RECENT MOLLUSK TRANSPLANTS INTO THE NORTH FORK HOLSTON RIVER IN SOUTHWESTERN VIRGINIA

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The North Fork Holston River originates near Sharon Springs, Bland County, Virginia, and flows 130 miles southwest into Tennessee where it joins the South Fork to form the mainstem Holston River. From 1894 to 1972 a chemical plant located along the North Fork near Saltville, Virginia, (mile 80) effectively eliminated stream life in much of the lower half of the river (Hill et al. 1974). Chemical and other wastes from this facility were dis-

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charged into the river and later into setting lagoons located along the banks of the river (Tennessee Valley Authority 1968). This plant ceased operation in 1972 because it could not economically comply with water quality standards.

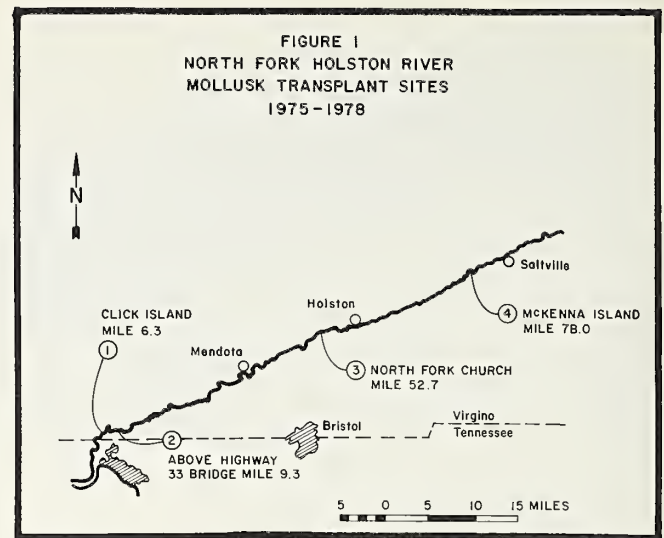
Ortmann (1918) reported 42 species and forms of freshwater mussels from the North Fork Holston River at and below Saltville, Virginia. Recent surveys in the North Fork indicate that a good mussel fauna still occurs above Saltville (Stansbery and Clench 1974, TVA unpublished 1976), however, the mussel fauna below Saltville largely has been extirpated (TVA unpublished 1976). Following the chemical plant closure in 1972 the Tennessee Valley Authority (TVA) initiated a sampling program in the North Fork to monitor the anticipated recovery of both fish and macroinvertebrate populations. This work was part of the Resto-

ration of Damaged Streams Project which was designed to evaluate and assist faunal recovery in the North Fork and Tuckaseigee Rivers. Recovery of the fish and bottom fauna, including the snail *Anculosa subglobosa* (Say 1825), occurred at surprisingly rapid rates. Between 1972 and 1975 no increase in mussel populations occurred. While this may reflect our inability to find juvenile mussels, it may also reflect the distance between mussel stocks and this uninhabited reach of river.

In October, 1975, 281 mussels representing 8 species were introduced into the North Fork at mile 6.3 (site 1). These specimens had been removed from the Clinch River at Kyles Ford (mile 189.6) by handpicking and had been placed in insulated containers during the same day trip to the North Fork. Subsequent similar transplants were made to a total of four sites from 1976 to 1978 (Figure 1). In all 2,887 mussels have been introduced into the North Fork (Table 1). The 16 species that these specimens represent are all known to have occurred in the river prior to 1900 (Ortmann 1918). Each transplanted specimen (except those moved in 1975) was aged, weighed, measured, and marked with a white epoxy number prior to placement into the substrate.

In August 1978, the Spiny River Snail *Io fluviatilis* (Say 1825) was reintroduced into the North Fork at river miles 6.3 and 9.3 (sites 1 and 2). A total of 716 specimens were taken from the Clinch River at Kyles Ford (mile 189.6) and Wallens Bend (mile 192.5) by handpicking and placed in insulated containers for transport to the North Fork. As with the mussels, each snail was weighed, measured, and marked with an epoxy number prior to placement into the substrate. *Io* had not been collected alive in this river since 1900 and those specimens came from "above the alkali works near Saltville" (Adams 1915).

To date, no statistical evaluation of the success of either the mussel or snail transplants have been made. Visits to the trans-



plant sites do indicate that at least some mussels and some *Io* specimens are still alive. Beginning in the fall of 1979, each transplant area will be surveyed to evaluate survival, rates of growth and reproductive success.

If the results of the evaluation are successful, additional transplants potentially including endangered species will be considered for this recovering upper Tennessee stream.

ACKNOWLEDGEMENTS

I wish to take this opportunity to thank Karl Henn and Steven Brown for their assistance in conducting field work.

Table 1. Mollusk Species Transplanted

	Site 1 MILE 6.3				Site 2 MILE 9.3	Site 3 MILE 52.7	Site 4 MILE 78.0	Species Totals
	1975	1976	1977	1978	1978	1975	1977	
Mussels:								
<i>Amblema costata</i> (Barnes 1823)	15	—	—	4	1	10	—	30
<i>Cyclonaias tuberculata</i> (Rafinesque 1820)	9	12	—	8	5	6	—	40
<i>Elliptio dilatatus</i> (Rafinesque 1820)	13	17	—	13	4	3	—	50
<i>Fusconaia barnesiana</i> (Lea 1838)	15	67	—	30	22	19	—	153
<i>Quadrula cylindrica</i> (Say 1817)	8	3	—	1	—	3	—	15
<i>Lasmigona costata</i> (Rafinesque 1820)	—	36	24	20	15	12	—	107
<i>Actinonaias carinata</i> (Barnes 1823)	100	98	152	171	101	205	—	827
<i>Actinonaias pectorosa</i> (Conrad 1834)	85	223	198	150	126	21	14	817
<i>Dysnomia capsaeformis</i> (Lea 1834)	—	10	—	3	—	5	—	18
<i>Lampsilis fasciola</i> (Rafinesque 1820)	—	—	—	—	3	—	2	5
<i>Lampsilis ovata</i> (Say 1817)	—	—	—	8	1	—	—	9
<i>Medionidus conradicus</i> (Lea 1834)	—	—	—	8	1	—	—	9
<i>Micromya nebulosa</i> (Conrad 1834)	—	18	—	—	—	—	—	18
<i>Proptera alata</i> (Say 1817)	36	—	—	3	—	15	—	54
<i>Ptychobranthus fasciolaris</i> (Rafinesque 1820)	—	14	—	2	2	1	4	23
<i>Ptychobranthus subtentum</i> (Say 1825)	—	143	105	72	64	6	322	712
Snail:								
<i>Io fluviatilis</i> (Say 1825)	—	—	—	270	446	—	—	716
Sub Totals	281	641	479	755	790	315	342	3,603
Site Totals		2,156			790	315	342	3,603

*Proposed Endangered.

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THE OBSERVATION OF GROWTH RINGS IN STATOLITHS FROM THE OMMASTREPHID SQUID, *ILLEXILLECEBROSUS*

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INTRODUCTION

To date studies of the population biology of squid have been hampered by the lack of a reliable technique for ageing. Age determinations and growth rate calculations have been restricted to attempts at equating size frequency modes with different brood or year-classes (Mesnil, 1977; Squires, 1967; Summers, 1971). However, complications arise even within a single year-class with overlapping size distributions due to the presence of mixed age groups possibly resulting from a protracted spawning period (Mercer, 1969).

Clarke (1965) suggested that 'age determinations from laminations of some kind would overcome these difficulties', similar to scale or otolith reading in fish. To investigate this, workers have examined the rings found in various body structures of squid such as beaks (Tinbergen and Verveij, 1945; Clarke, 1965) radulae (Wirz, 1963) but no method was discovered.

Evidence of rings in cephalopod statoliths has been reported by various authors (Brothers *et al.*, 1976; Clarke, 1966; Lipinski, MS 1978; Young, 1960). Lipinski (MS 1978) speculated that the rings in statoliths of *Illex illecebrosus* might be daily rings within the nucleus and monthly rings beyond this zone.

The purposes of this study were to 1) examine the microstructure of the rings found in the statoliths of *Illex illecebrosus* and determine if they were 'true' rings formed by differential deposition of CaCO_3 and organic material and not an optical aberration as was suggested by Dilly (1976), 2) describe the growth of statoliths and the relationship between the number of rings laid down and mantle length and 3) by means of back calculation determine if the rings had a chronological interpretation as originally proposed by Lipinski (MS 1978).

MATERIALS AND METHODS

Statoliths from 129 squids (65 females, 64 males) were examined. Their mantle lengths ranged from 1.5 to 25.0 cm. Of these, 35 statoliths were collected from squids caught by the Soviet research vessel RTM Belogorsk in March-May 1979 during a plankton cruise in the area of the Gulf Stream off the Canadian Atlantic coast. The remaining statoliths were collected in either June 1978 from a bottom trawl survey on the southwest

slope of the Grand Banks or from Newfoundland inshore commercial samples obtained on a monthly basis from 10 June to 17 November 1978.

The statoliths are paired calcareous concretions located in the ventro-posterior region of the cartilaginous skull (Fig. 1) in the anterior end of two adjacent cavities, the statocysts, in an area known as the *macula princeps* (Clarke, 1978; Young, 1964). By means of x-ray diffraction the composition of the statoliths was determined to be aragonite for *Illex illecebrosus* which was similar



Fig. 1. X-ray of head region of *Illex illecebrosus*. Arrow points to area of head where statoliths are found.

to that found for the composition of other cephalopod statoliths (Clarke, 1978; Dilly, 1976).

Two methods were employed for the extraction of statoliths. First by dissection using a method similar to that described by Clarke (1978). The second technique made use of the differing chemical composition of the cartilaginous skull and the aragonitic statoliths. Ordinary bleach (NaHClO_3) was effective in dissolving away the skull while leaving the statoliths intact. The latter method is preferred since no painstaking dissection is required.

The statolith was first embedded in Ward's cement and mounted on a glass microscope slide. The statolith was ground on its concave antero-lateral plane (Fig. 2) against the frosted surface of another microscope slide until concentric rings were clearly visible along a radius from the nucleus to the outer edge of the statolith. The rings which have been defined as a pair of light and dark adjacent bands (Taubert and Coble, 1977) were counted with the aid of a compound microscope at magnifications ranging from 250-550X. To examine the microstructure of the statoliths a scanning electron microscope (SEM) (Cambridge Stereoscan Mark II A) was used (Fig. 3a, b). The ground surface of each statolith was polished with 1 μ diamond paste, etched with 0.1N HCl for 3 to 4 minutes, mounted on an aluminum stub with double-sided tape and finally coated in a vacuum evaporator with 150 Å of gold.

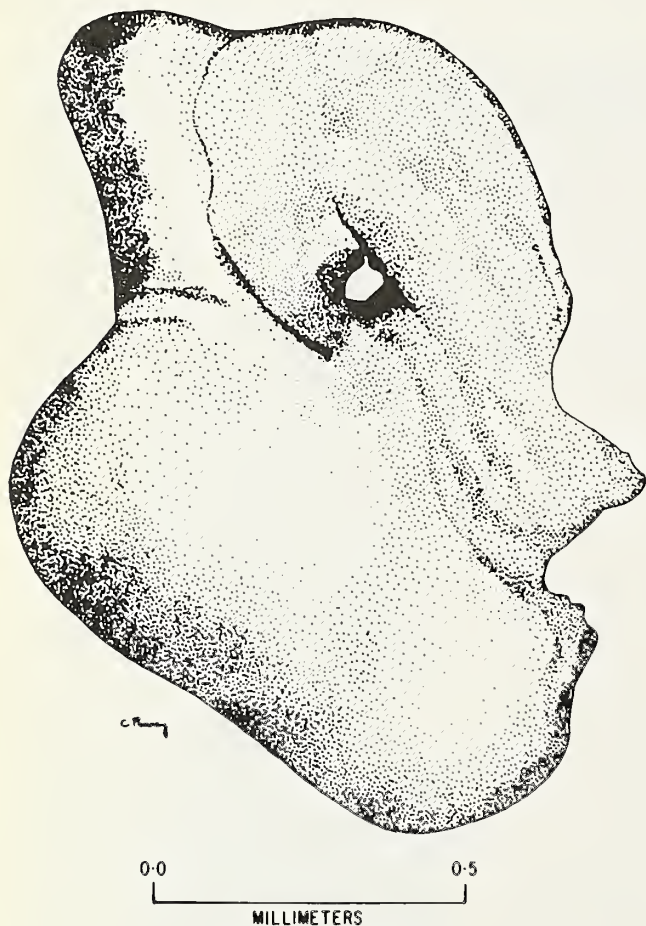


Fig. 2. Illustration of a statolith from *Illex illecebrosus* showing grinding surface (antero-lateral view). Top of photograph is the ventral side of the statolith.

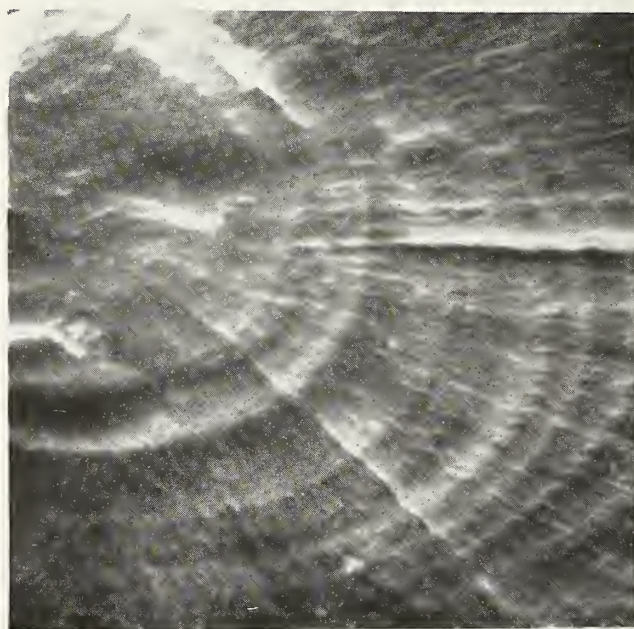
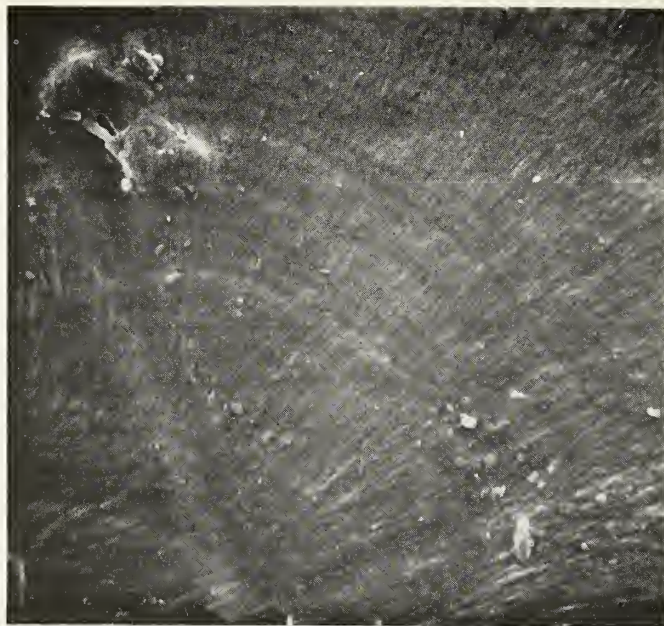


Fig. 3a (top). Scanning E.M. photograph (1500X) of the ground and etched surfaces of a statolith showing numerous rings. Fig. 3b (above). Scanning E.M. photograph (7300X) of etched rings surrounding the nucleus. The nucleus itself may be made up of mucopolysaccharide and mucoprotein (Lim, 1973).

The maximum statolith radius was measured with the aid of a 2 mm scale micrometer by determining the maximum distance outwards from the center of the nucleus (usually in a dorsal direction) to the edge of the statolith.

The back calculation procedure was adapted from Ricker and Lagler (1942) for back calculating fish lengths from a non-linear

curve. The following formula was used to correct a ring count that did not correspond to the ring count for a squid of that mantle length:

where $R = R_n R_n$

R

R_n = adjusted ring count to an earlier sampling date

R = average ring count for an animal of the observed mantle length

R_n = estimated ring count at an earlier sampling date assuming one day

R = observed ring count on statolith

RESULTS

Observation of rings

In this study rings were observed both under the light microscope and SEM. This confirms earlier observations by other authors (Brothers *et al.* 1976; Clarke, 1966; Lipinski, MS 1978; Young, 1960). Dilly (1976) could not find any evidence of rings in the statoliths that he examined.

Fig 3 (a, b) shows SEM photographs of prepared statoliths. The darker band of each ring represents an area where the acid etching removed more CaCO_3 than in the lighter areas which may be made up of higher concentrations of organic material as in fish otoliths (Degens *et al.*, 1969). The etching would indicate that the rings were 'true' rings and not merely thin parts of the statolith passing more transmitted light than the thicker parts, as suggested by Dilly (1976).

With transmitted light the rings were also evident as pairs of dark and light bands. Fig. 4 (a, b, c, d) shows photographs of ground statoliths from animals of 1.7-22.0 cm mantle length. In general the rings in the nuclear area (<30 rings) tended to be narrower ($1.0\text{--}2.5\ \mu$) than the peripheral rings ($2.0\text{--}5.0\ \mu$). In many statoliths the nuclear area was defined by a relatively dark ring (Fig 4d). The fine rings within the nucleus may have corresponded to the "juvenile statolith" zone of Lipinski (MS 1978). Beyond this zone, toward the periphery of the statolith, he counted relatively fewer rings than were observed in this study (Fig 4a, b, c, d).

Ring counts were compared statistically between readers and between individual statoliths of a pair to investigate the precision of the results. In a sample of 16 statoliths read by two readers

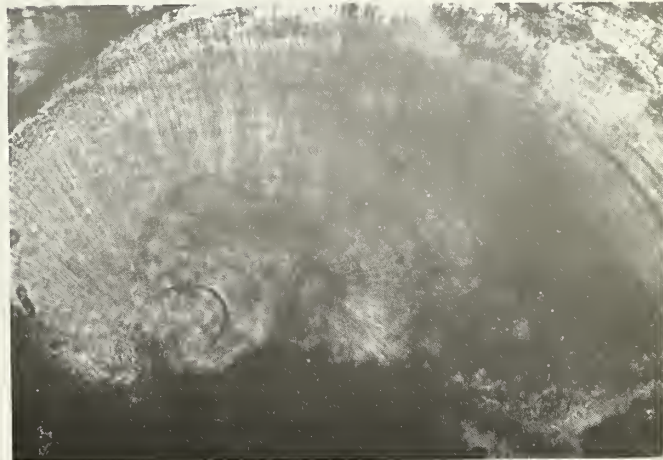
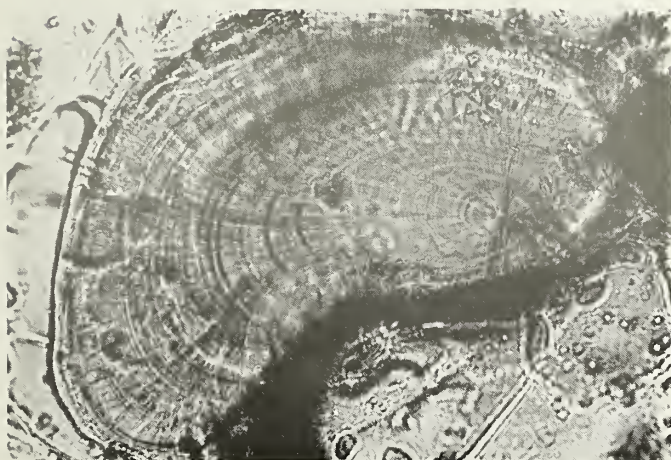
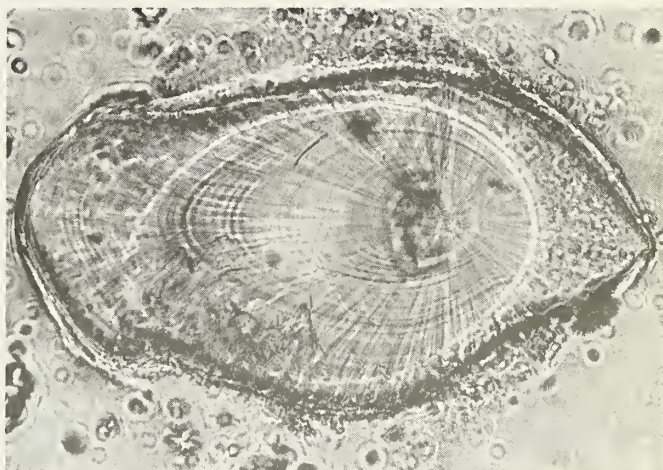
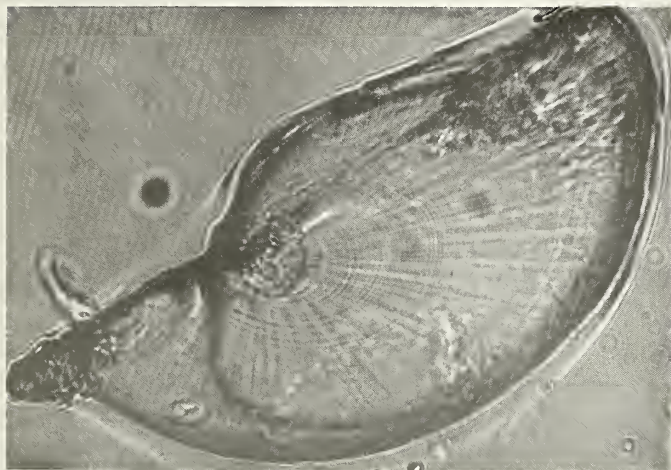


Fig. 4. Photographs of ground statoliths (using transmitted light) from squid of various sizes. 4a (above left). Mantle length = 1.7 cm juvenile, magnification = 525X. Fig 4b (above right). Mantle length = 4.2 cm female, magnification = 350X. Fig 4c (bottom left). Mantle length = 11.2 cm female, magnification = 275X. Fig 4d (bottom right). Mantle length = 22.0 cm female, magnification = 250X.

without *a priori* knowledge of the other reader's count it was determined that there was no significant difference between both readers' ring counts ($t = 0.14$, at the conventional 5% probability level) (Sokal and Rohlf, 1969, p. 331). Also there was no significant statistical difference in the ring counts between individual statoliths of a pair in a sample of 40 pairs of statoliths read by the same reader ($t = 0.91$, at the conventional 5% probability level) (Sokal and Rohlf, 1969, p. 331).

Relationship between mantle length and maximum statolith radius

The maximum statolith radius was measured for 82 squid. The results of these measurements were stratified into one-cm mantle length groups and the mean radius was calculated for each length group. The animals measured ranged in mantle length from 1.5 to 25.0 cm. A curvilinear fit to the data (Fig. 5) ($y = 48314.6 x^{2.69}$, $r^2 = 0.96$, $n = 21$) proved to be statistically significant (F-test, $P = 0.05$). The growth of the maximum statolith radius (Fig. 5) was allometric particularly over the smaller mantle lengths (< 10.0 cm). At larger mantle lengths (> 10.0 cm) the statolith growth became more isometric. This is similar to the bony structure radius-body length relationship in many fish species (Casselman, 1974; Fagade, 1974; Ricker and Lagler, 1942; Taubert and Coble, 1977). Dilly (1976) stated that any direct correlation between statolith and body size was obscure, but he noticed that statoliths from large animals were generally larger than those from smaller animals.

Relationship between mantle length and ring count

The relationship between mantle length and ring count was determined and curves were fitted separately for statoliths taken

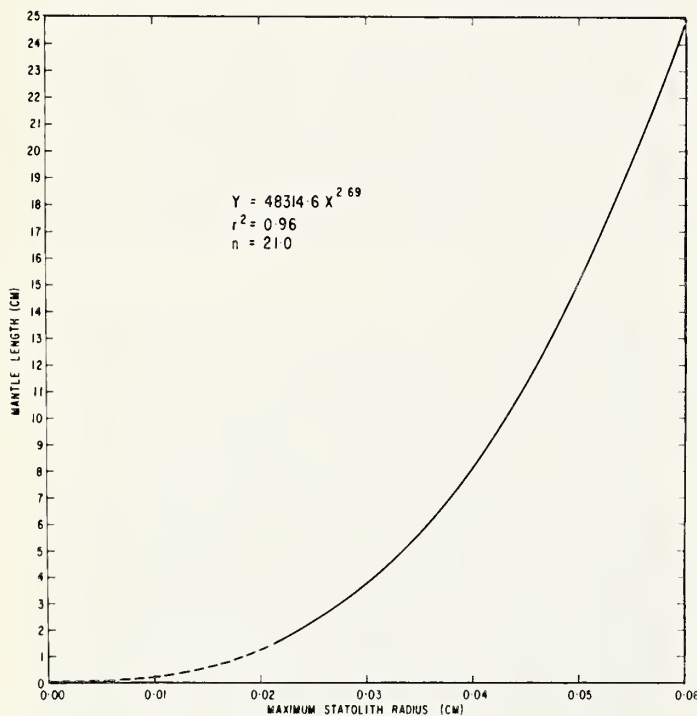


Fig. 5. Maximum statolith radius (x) - mantle length (y) relationship. $Y = 48314.6 x^{2.69}$. Solid line represents the range of observed values. Dashed line represents extrapolated value from the fitted curve.

from 1) males ($y = 2.5 \times 10^{-5} x^{2.68}$, $r^2 = 0.91$, $n = 64$), 2) females ($y = 4.5 \times 10^{-4} x^{2.12}$, $r^2 = 0.89$, $n = 65$), 3) both sexes combined ($y = 3.07 \times 10^{-4} x^{2.19}$, $r^2 = 0.87$, $n = 29$). Ring count was chosen as the independent variable since the curve in (Fig. 6) for both sexes combined was used later to back calculate mantle lengths. A curvilinear fit to the data also best described the probable relationship over the smaller size ranges not analyzed in this study (2.5 cm for females; 2.7 cm for males).

Back calculation

Fig. 7 shows a plot of percent frequency of mantle lengths by sex for each of the samples collected in 1978 and gives the modal mantle length range for animals in each sample from which statoliths were examined. These length-frequency samples showed an increasing range of mantle length modes for the months June through September (males) and June through October (females). However, from September to November there was an apparent slowing down in the population's rate of growth as indicated by the mantle length modes.

The monthly mantle length modes identified in Fig. 7 could be compared with back calculated mantle lengths, similar to the

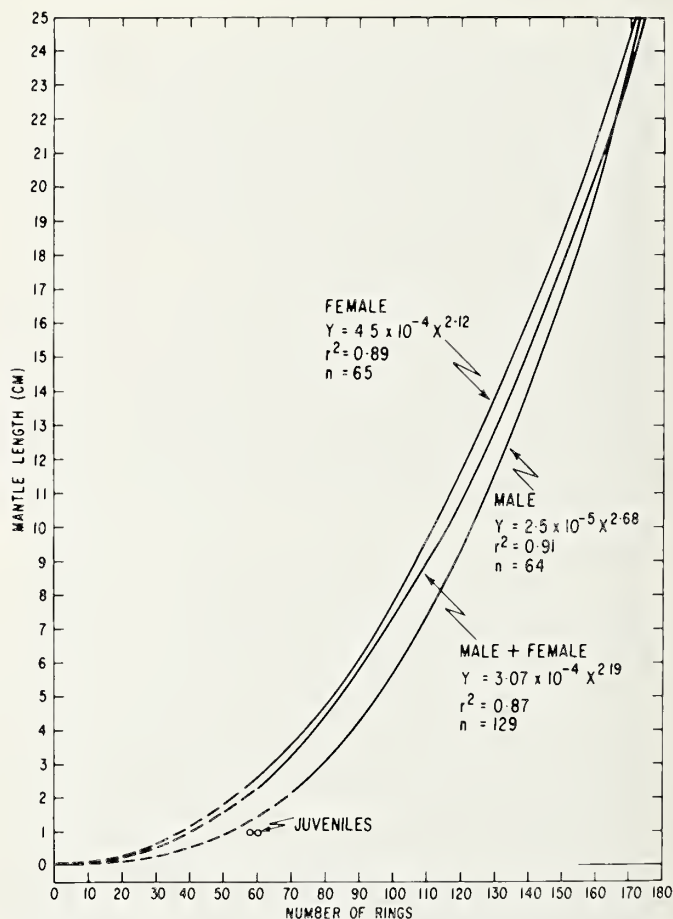


Fig. 6. Ring count (x) - mantle length (y) relationship. Curves were fitted to values for males ($Y = 2.5 \times 10^{-5} x^{2.68}$) for females ($Y = 4.5 \times 10^{-4} x^{2.12}$), and for both sexes combined ($Y = 3.07 \times 10^{-4} x^{2.19}$) from 1978 and 1979 data. Solid line represents the range of observed values. Dashed line represents extrapolated values from the fitted curve.

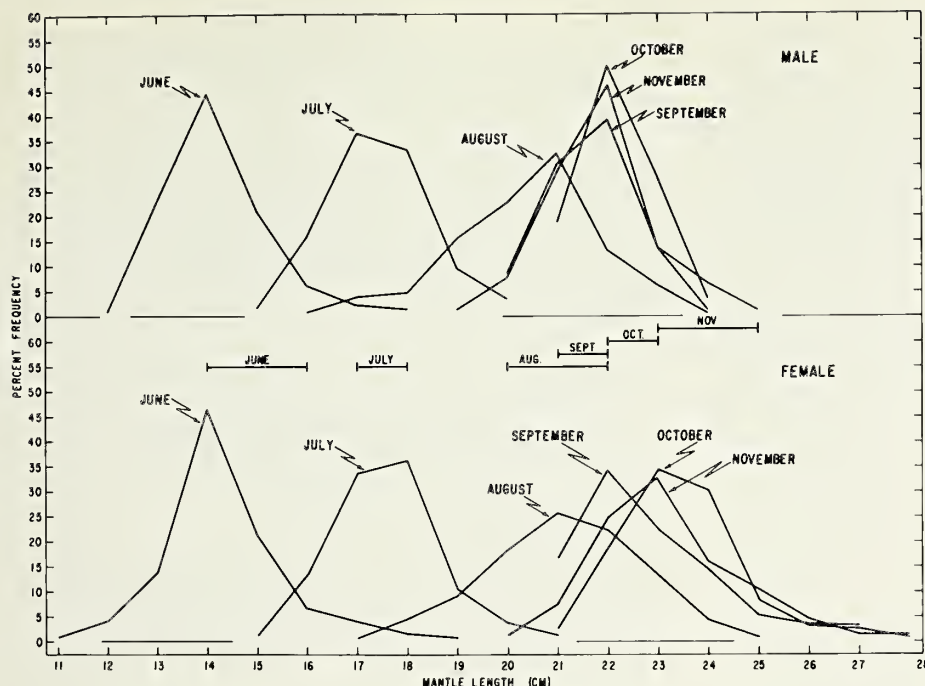


Fig. 7. Size distributions from inshore samples taken in 1978 from June to November. Horizontal solid lines show length intervals for each sample from which statoliths were read.

cohort analysis using beak growth rings by Clarke (1965), if it was assumed that in the 1978 fishing season there was only one brood of squid that were spawned within a relatively short period of time. Squires (1957) concluded that this was the case because length distributions showed increasing monotone growth throughout the season (i.e. with age).

Both maximum statolith radius ($r^2 = 0.95$) and ring count ($r^2 = 0.87$, both sexes) predicted mantle lengths equally well since an analysis of covariance on the logarithmic transformation of the two relationships showed no difference between the slopes ($F_{1,139} = 2.08$, not significant at the conventional 5% probability level). For purposes of back calculation in this study the ring count-mantle length relationship (Fig. 6, both sexes) was employed adapting the method of Ricker and Lagler (1942) for back calculating fish lengths from a non-linear curve. The back calculation procedure was carried out assuming that one ring represented a time interval of one day.

In Fig. 8 the mean mantle lengths, back calculated from all successive samples, had much lower values (10.6 - 11.2 cm) than the expected values (found on the equisector, Fig. 8) had. Since tagging results from inshore Newfoundland have shown that individual *Illex* can remain in the same location for at least one month even in late season, it was through useful to derive back calculated mean mantle lengths only from statoliths examined from the immediately successive sampling date and compare those values with the expected values. These back calculated mean mantle lengths were also lower (1.4 - 10.2 cm) and their confidence limits did not overlap the expected mean mantle lengths but were much closer to the expected values than were the mean mantle lengths back calculated from all successive sample data.

DISCUSSION

Possible chronological interpretation of rings

There was little evidence from back calculation in this study that the rings could be interpreted as chronological marks. The correlation of back calculated mean mantle lengths with expected

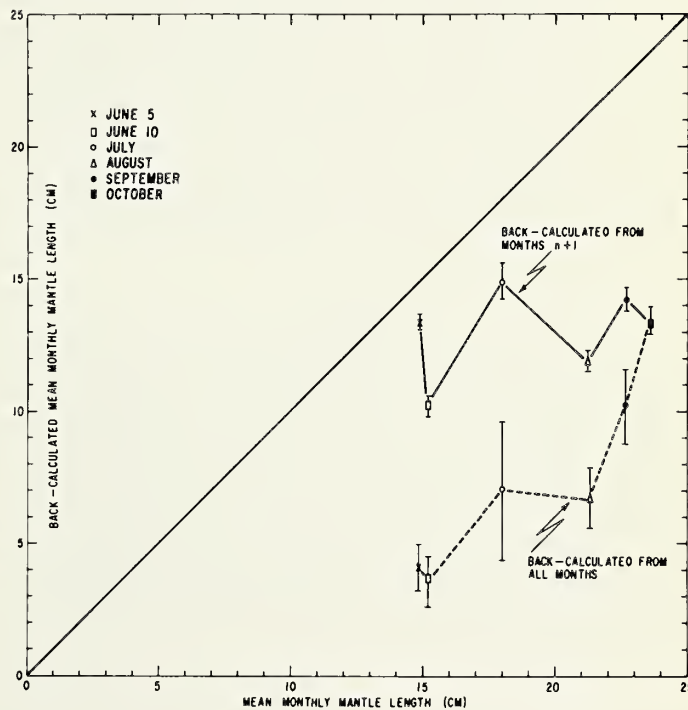


Fig. 8. Monthly mantle length mode from size distributions - monthly back calculated mean mantle length relationship from 1978 samples. Solid line represents mean mantle lengths back calculated from the immediately successive sample. Dashed line represent mean mantle length back calculated from all successive samples. Equisector represents expected modal mantle length values.

mantle length modes improved when an attempt was made to eliminate the possible biasing of late season migration (Squires, 1957). This apparent lack of agreement may have been due to the presence of mixed age-groups within a single year-class spawned over a protracted season hypothesized by Mercer (MS 1975) who observed bimodal and trimodal length distributions in some years. The presence of mixed age-groups would have made it impossible to take statolith samples from a single monthly mantle length mode and would have complicated the validation of ageing by back calculation.

There has been very little published material on growth rates of squid from known age specimens. However the inferred growth rate of *Illex illecebrosus* (Fig. 6) is quite similar to the measured growth rate of laboratory-raised *Loligo opalescens* if a growth ring is assumed to represent a time interval of one day, (Won Tack Yang, Marine Biomedical Inst., Texas, pers. comm). Although this is a comparison of growth rates between two different species of squid the similarity of the curves suggests that a chronological interpretation of the rings cannot be discounted.

It is possible that the rings observed in the statoliths were simply growth rings and not chronological marks. Dilly (1976) felt that any diurnal rhythm is probably too rapid to affect statolith crystal growth. Growth rings in freshwater fishes were laid down on a daily basis according to a 24-hour, light-dark cycle which entrained an internal, diurnal clock assuming that a supply of food was available, (Taubert and Coble, 1977; Ottaway, 1978). The chronological interpretation of rings may be more difficult for a marine animal that is an opportunistic feeder such as *Illex illecebrosus* (Ennis and Collins, 1979) which may spend several days without feeding. During periods of starvation, Bilton (1974) showed that rings did not form in fish scales. The percentage of empty stomachs and high rate of cannibalism (Squires, 1957; Mercer, MS 1965) among squid sampled in inshore Newfoundland waters may indicate temporary scarcity of food supply and probable sporadic feeding. If food availability is a limiting factor in the formation of daily rings then perhaps statoliths should be examined from *Illex illecebrosus* found in Northwest Atlantic offshore waters where they have been shown to feed on a 24-hour cycle (Amaratunga *et al.*, MS 1979).

SUMMARY

Rings found in statoliths from *Illex illecebrosus* were found to be more numerous than previously reported. The rings were shown to be 'true' rings and not merely optical aberrations.

The number of rings increased with mantle length but did not represent chronological marks based on cohort analysis for samples from inshore Newfoundland. However, age validation may have been complicated by the presence of mixed age-groups.

Other age validation techniques should be tried in the future such as examining statoliths from squid of known age or putting a 'time' mark on statoliths using an antibiotic such as tetracycline (Weber and Ridgeway, 1967).

ACKNOWLEDGEMENTS

We appreciate the assistance of Cynthia Penney, artist; Carolyn Emerson, electron microscopist; Herb Mullett, draftsman; Gordon King, photographer; Janice Lannon, typist. Special thanks to Joseph Drew who prepared and read many of the statoliths. We also thank Dr. G.P. Ennis who initiated the study and reviewed and criticized the manuscript. Dr. G.W. Winters provided many helpful suggestions and criticisms of the analyses presented here.

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THE PNEUMOSTOME OF
THE TERRESTRIAL PROSOBRANCH SNAIL,
HELICINA ORBICULATA (SAY, 1818)

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A pneumostome is a restricted opening which regulates the passage of air into the mantle cavity, or part of it, in some aquatic and terrestrial snails. Although the anatomy of helicid snails has been studied extensively, notably by Bourne (1911) and H.B. Baker (1925, 1926, 1928), the presence of a pneumostome in the Helicinidae has not hitherto been recognized. The reason for this neglect is simple: the pneumostome in those snails can be seen only in the living animal (Fig. 1).

There is no gill in the mantle cavity of these terrestrial prosobranch snails; the roof of the mantle cavity (that part of the cavity subtending the body whorl of the shell) is often described as vascular near its upper end, further suggesting that this is an important site of gas transfer between the air and the blood of the snail. The term 'lung' has been applied to the mantle cavity of the helicid snails by both Bourne and Baker.

Preserved specimens were all that either author studied, although Baker collected some of his material alive, and he even described the living animal briefly (Baker, 1928:26). Preserved specimens show a thickened mantle margin, but there is no apertural septum connecting the mantle margin and the body

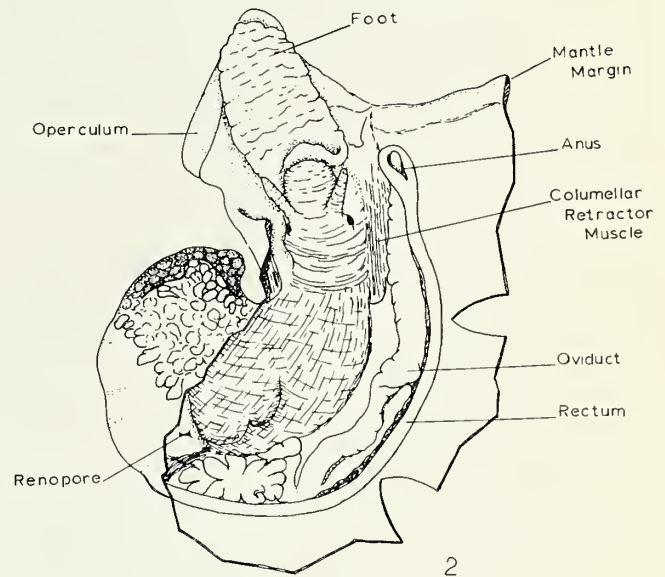


Figure 2. Specimen of *Helicina orbiculata* with mantle cavity opened. Note lack of attachment of mantle margin to body stalk.

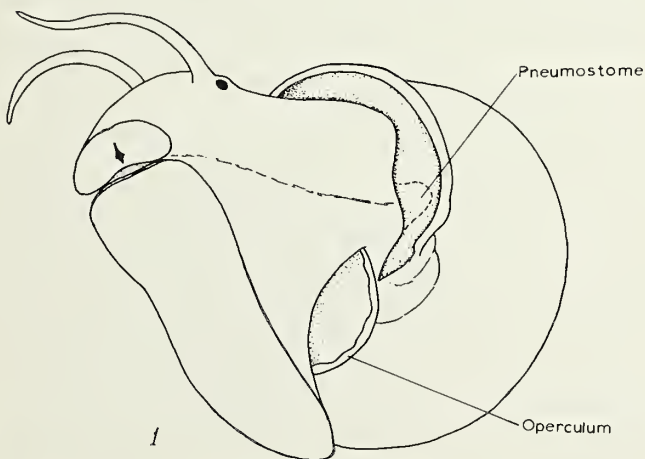


Figure 1. View of basal (left) side of a live *Helicina orbiculata*. Position of the pneumostome when open is shown by the dashed line. Specimen from Houston, Texas. Shell diameter, 6.5 mm.

stalk, such as occurs in pulmonate snails. Instead, the lower, or apertural end of the mantle cavity is broadly open to the exterior (Fig. 2; vascularization of the mantle cavity roof not shown).

In living *Helicina orbiculata*, the thickened mantle margin completely occludes the opening into the mantle cavity. Several times a minute the mantle margin on the left, or basal, side is temporarily pulled away from the body stalk in such a way that an oval passage into the mantle cavity is formed (Fig. 1). This is the pneumostome. The snail may continue to crawl steadily while the pneumostome is open, without any pumping motion.

In those stylommatophoran and basommatophoran pulmonate snails which have a multi-whorled shell, there is a transverse partition connecting the roof of the mantle cavity to the body stalk, slightly inside and parallel to the apertural margin of the shell (Figs. 3, 4 and 5). This permanently separates the lung from the lower (hypopneural) mantle cavity. In both those groups the pneumostome is a permanent hole in the transverse partition, which can be observed in the preserved as well as in the living animal. But the pneumostome of the Stylommatophora is closed by a sphincter muscle, which is absent in the Basommatophora. In the latter group the opening is closed by a lappet, called a 'siphon' by Harry (1964:369), who discussed the distribution of the two pneumostomal types within those restricted pulmonate groups and their near relatives.

The diaphragm (or floor of the mantle cavity, opposite the roof) of both pulmonate groups is muscular, and it contracts and relaxes to effect the exchange of air through the pneumostome. Whereas the Stylommatophora can continue to crawl while the pneumostome is open, the Basommatophora apparently must remain stationary, or merely float beneath the surface film of water, which is broken precisely at the pneumostome to allow air to enter the lung. The Pulmonata do not pump the body while air is being exchanged. In *Helicina*, the diaphragm is very slightly muscular.

The tropical freshwater snails of the family Pilidae (Ampulariidae of authors) are essentially aquatic, although some crawl over the land in moist weather, and most (not *Marisa*, however) crawl above the water to lay their eggs on emergent plants (*Typha*, etc.) or rocky surfaces near the water. The single gill on the roof of the mantle cavity of the Pilidae is typical of that of most pectinibranch prosobranchs (Mesogastropoda and Neogastropoda). There is no transverse apertural septum. The mantle margin, only slightly thickened, does not occlude the apertural end of the mantle cavity, which is thus broadly open to the

exterior. By the action of the cilia of the gill, water enters on the left (basal) side and exits on the right (sutural) side of the mantle cavity.

On the left and right sides of the body stalk, behind the eyes, are nuchal lappets. The left one is capable of great extension, and is rolled into a tube, with the free lateral margins brought together dorsally. This siphon is obviously not homologous to that of the other siphonate pectinibranch snails. The siphon in those species arises from the mantle, the slit is ventral when the siphon is rolled into a tube, and it admits only water. In the Pilidae the nuchal siphon admits only air, never water.

Pilid snails frequently crawl to the water surface, and break the film with the tip of the siphon. The foot is always attached to some firm structure while this is done, and the body of the snail performs a pumping motion. This peculiar motion is evidently caused by alternately contracting and relaxing the columellar retractor muscle, which is the only attachment of the animal to the shell.

The air inhaled by the pumping motion seems not to go to the general mantle cavity, but only to the special elongate sack in the roof thereof (Fig. 6). The lower end of this special lung is some distance from the mantle margin, and, in dissected specimens, the lower end of the sack appears to be far removed from the inner end of the siphon. On the lower end of the lung sack there is a short, narrow slit, the pneumostome, which is closed by a sphincter muscle. Demian (1965) has given a detailed account of the aerial breathing of *Marisa cornuarietis* (Linne 1758), and evaluated the rather extensive literature which has developed about it, during the century and a half since aerial respiration of pilid snails was first discovered.

In the pulmonates, the anus in all and the renopore in many are associated with the pneumostome, the rectum passing through the transverse apertural septum. Thus the anus, and the renopore when this is at the end of a ureter, are on the same side as the pneumostome, whether the visceral asymmetry of the snail is dextral or sinistral. The reproductive system of the pulmonates opens on the cephalopedal mass, in contrast to the prosobranchs. But the reproductive openings are on the same side as the pneumostome in pulmonates, again regardless of which asymmetry the viscera have. In the prosobranchs, the reproductive system opens inside the mantle cavity (or, correctly, the medial dorsal extension of it). In pectinibranch prosobranchs, which include the Pilidae, and the Neritacea (which include the Helicinidae) among the aspidobranth prosobranchs (Archaeo-

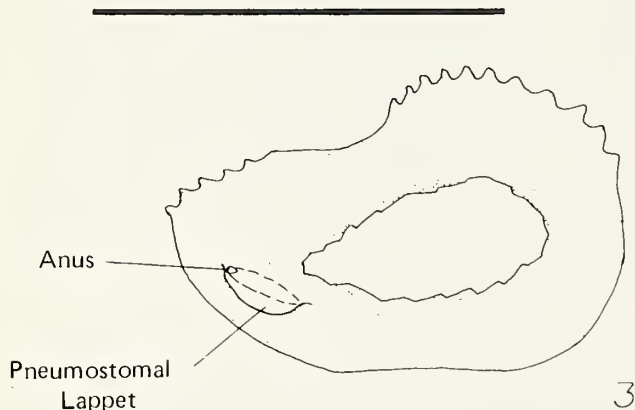


Figure 3. Ventral (or apertural) view of mantle collar, cut away from the body stalk, of the basommatophoran, *Physa marmorata* Guilding 1828, from Puerto Rico. Shell height, 13.5 mm, apertural height, 9.5 mm.

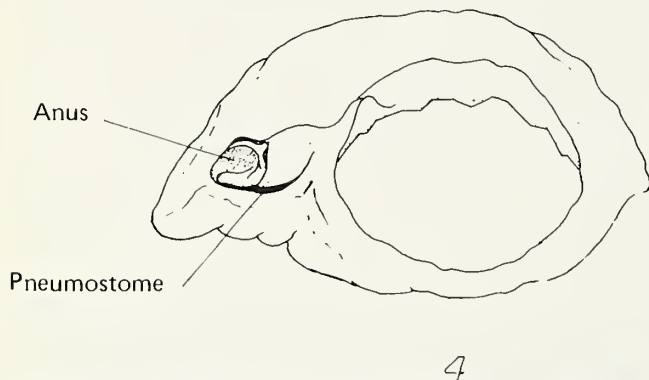


Figure 4. Apertural view of mantle collar, cut away from the body stalk, of the stylommatophoran, *Achatina fulica* Ferussac 1821, from Saipan, Marianna Islands. The pneumostome was open in this preserved specimen, revealing the anus and renopore; shell height 100 mm, apertural height 50 mm.

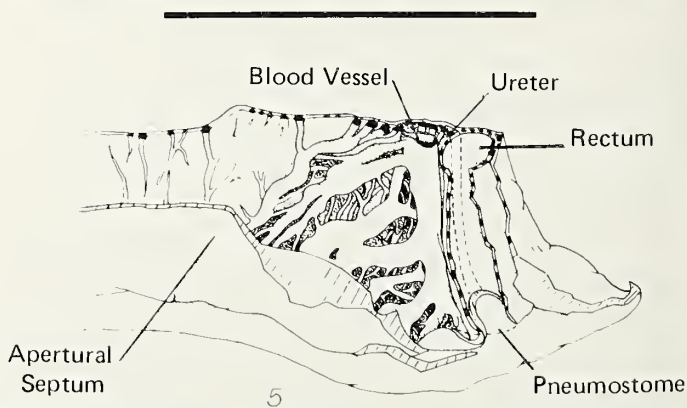


Figure 5. *Achatina fulica*. View of mantle roof adjacent to the sutural angle of shell aperture, showing intimate relation of ureter and rectum to pneumostome.

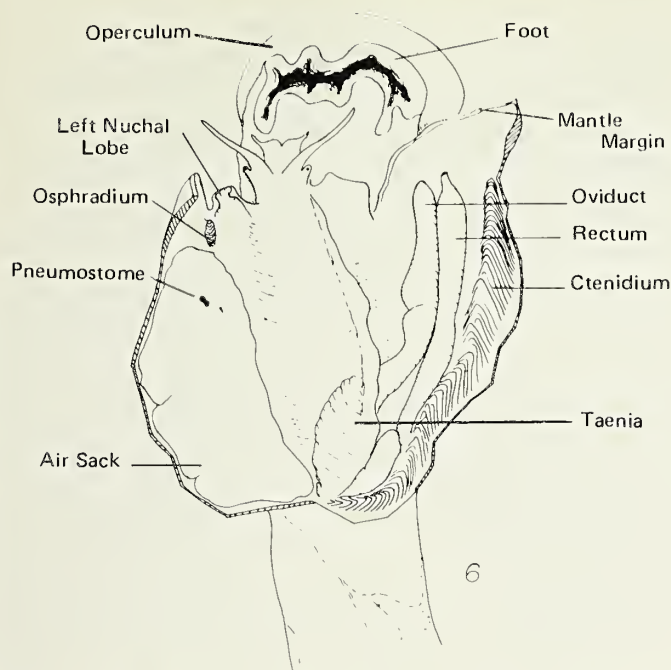


Figure 6. The prosobranch, *Marisa cornuarietis* (Linne, 1758) with mantle cavity opened, to show air sack and pneumostome remote from mantle margin. Specimen from Puerto Rico. Diameter of this planispiral shell, 30 mm. See also Demian, 1965, Fig. 2.

gastropoda), the tubular extensions of the reproductive system through the median dorsal mantle cavity lie along the rectum, which is also prolonged into that cavity. Both the rectum and the reproductive tube are on the opposite side of the body from the

pneumostome in Pilidae and Helicinidae. In prosobranchs, the renopore is near the apex of the median mantle cavity, and not extended as a ureter through the wall of this cavity, in contrast to many pulmonates. The renopore is shown in Figure 2, but not in Figure 6.

There are thus four types of pneumostomal mechanisms among air breathing snails. Whether other terrestrial prosobranchs have a pneumostome remains to be determined, and studies on the living animals may be necessary to elucidate the point.

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UNIONACEAE OF ARKANSAS: HISTORICAL REVIEW, CHECKLIST, AND OBSERVATIONS ON DISTRIBUTIONAL PATTERNS

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INTRODUCTION

The occurrence and distribution of the Unionacea in Arkansas has not been intensively studied, as noted by LaRocque (1962). The available literature is summarized in Table 1. An indication of the degree of development of the fauna is given by Coker (1919). He reported that between 1912 and 1914 the freshwater mussel industry in Arkansas was responsible for half the yearly production from the Interior Basin south of the Missouri River including the Ohio River and Gulf drainages. Also, the White River was the fourth most productive river in the United States, receiving the second highest yearly price per ton of shells.

Currently, several Arkansas drainages are being studied by the authors. Additional information has been obtained from personal collections of the authors and examination of over 1300 lots of Arkansas unionaceans at the University of Michigan Museum of Zoology, Harvard University Museum of Comparative Zoology, U.S. National Museum of Natural History, University of Colorado Museum, and University of Arkansas Museum.

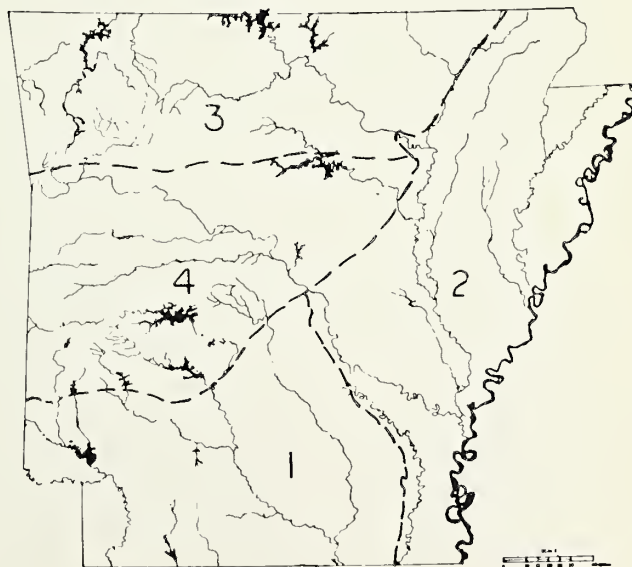


Figure 1. Physiographical regions and major drainages of Arkansas. 1—West Gulf Coastal Plain, 2—Mississippi Alluvial Valley, 3—Ozark Plateaus, 4—Ouachita Mountains

PHYSIOGRAPHY OF ARKANSAS

Geomorphologically, Arkansas can be generally classified as Gulf Coastal Plain, comprised of the West Gulf Coastal Plain and the Mississippi Alluvial Valley in the south and east, respectively, and the Interior Highlands, which includes the Ozark Plateaus and the Ouachita Mountains in the north and west, respectively

(Figure 1). The Ozarks can be characterized as a "dome" with a radial drainage pattern. The Boston Mountains form a barrier between the drainages of the more northern Ozark plateaus and the Arkansas River. The Arkansas River approximates the division between the Ozarks and the Ouachitas, which form east-west ridges (Thornbury, 1965; State of Arkansas, 1974).

Table 1. Literature pertaining to Arkansas Unionidae.

A. Type descriptions.

T.A. Conrad (1836)
I. Lea (1852)
I. Lea (1862)
W.A. Marsh (1891)
C.T. Simpson (1900a)

C.T. Simpson (1900b)
J.H. Ferriss (1900)
A.E. Ortmann and B. Walker (1912)
H.E. Wheeler (1914)
L.S. Frierson (1927, 1928)

Subject

Unio occidentalis
U. lamarckianus, *U. powellii*, *U. reeveianus*, *Anodonta opaca*
U. grandidens, *U. arkansasensis*
U. pilsbryi, *U. pleasii*
Ptychobranchus clintonensis, *Pleurobema brevis subelliptica*, *P. argentea pannosa*
U. gibbosus delicatus
Lampsilis simpsoni
Arkansia wheeleri
Fusconaia selecta
Lampsilis rafinesqueana, *L. streckeri*

B. Species lists and distributional surveys in Arkansas.

R.E. Call (1895)
S.E. Meek (1896)
E.G. Vanatta (1910)
S.E. Meek and H.W. Clark (1912)
H.E. Wheeler (1914)
A.A. Hinkley (1916)
H.E. Wheeler (1918)
B.A. Branson (1966)
M.E. Gordon, et al. (in press)

Arkansas in general
St. Francis River
Ouachita River
Buffalo River
Cache River
White River, North Fork White River, Black River, Spring River
Clark County
White River, Kings River
Illinois River

C. Benthic faunal surveys including unionaceans

Babcock and MacDonald (1973)
Kittle, et al. (1974)
Arkansas Eastman Company (1974)
M.E. Cather and G.L. Harp (1975)
C.J. Latimer (1975)
L.R. Kraemer (1976)
J. Rickett (in press)

Buffalo River
Illinois River
White River
Northeastern Arkansas creeks
Cache River
Arkansas River Navigation System
Flat Bayou

D. Miscellaneous studies.

R.E. Call (1885)
C.T. Simpson (1900)
A.E. Ortmann (1912)
A.E. Ortmann (1913-1916)
C.T. Simpson (1914)
A.E. Ortmann (1917)
B. Walker (1918)
A.E. Ortmann (1918)
A.E. Ortmann (1919)
R.E. Coker (1919)
T.K. Chamberlain (1934)
W.P. Brann (1950)
A. LaRocque (1962)
D.H. Stansbery (1970)
L.R. Kraemer (1970)
B.D. Valentine and D.H. Stansbery (1971)
R.I. Johnson (1978)

Mississippi Valley
U.S. in general
Systematics
Unionidae in general
Unionidae in general
Systematics
Systematics
Systematics
Systematics
Freshwater mussel industry
Anatomy-biochemical
Freshwater mussel industry
References
Endangered species
Behavior
Lake Texoma
Plagiola (= *Dysnomia*)

CHECKLIST

Sixty-two species and six ecophenotypes with subspecific classification have been recorded from Arkansas (Table 3). These records have been confirmed by specimens in the authors' personal collections or the collections of the previously mentioned museums. Another seven species are suspected of occurring, presently or formerly, in Arkansas (Table 2). These species either have been listed in the literature without a voucher specimen being located, have a questionable taxonomic status, or have been listed as possible elements of the Arkansas fauna by previous authors (e.g. Call, 1895). Nomenclature used is generally consistent with that of Ortmann and Walker (1922).

Table 2. Unionid species suspected of occurring in Arkansas.

<i>Plethobasis cyphus</i>	<i>Glebula rotundata</i>
<i>Elliptio crassidens</i>	<i>Dysnomia florentina</i>
<i>Obovaria subrotundata</i>	<i>Proptera alata</i>
<i>Pleurobema cf. clava</i>	

DISCUSSION

Distribution of the Unionacea in Arkansas when compared to general distribution within the Interior Basin reflects four distinct faunal affinities. These can be characterized as species from the southern Interior Basin-Gulf drainage, northern Interior Basin, the endemic Interior Highlands fauna ("Ozark" of H. and A. van der Schalie, 1950), and those that seem to occur throughout the Interior Basin. The occurrence of these faunal assemblages can be correlated with the geological history of the Interior Highlands, the periodic isolation of these highlands, and their function as biological refugia.

Certain species (e.g. *Proptera purpurata*, *Villosa lienosa*) which are typically distributed through the southern Interior Basin and Gulf drainages range north into the Ozarks. Their distributional limits approximate the shorelines of the Cretaceous and Tertiary embayments over the Gulf Coastal Plains (Thornbury, 1965; State of Arkansas, 1974). The Interior Highlands may have functioned as refugia for these southern species during these embayments. The disjunct distribution of *Lampsilis streckeri* may be a result of these embayments. The curious distribution of Arkansas Oak (*Quercus arkansana*) reflects the same geomorphological history. Found only very locally in Arkansas, Alabama, Georgia, and Florida, this primitive species is restricted to areas along the former Cretaceous shoreline (State of Arkansas, 1974).

Relict populations of species normally associated with the Cumberland region (e.g. *Cumberlandia monodonta*, *Dysnomia* spp.) have been found in the Interior Highlands. Johnson (1978) postulates that *Dysnomia* may have inhabited the region prior to the Cretaceous. The Interior Highlands and Cumberland regions are similar geologically and physical connections may have existed (Walker, 1917; Thornbury, 1965). Faunal evidence for such connection has been given by H. and A. van der Schalie (1950) and Johnson (1978). Embayments may have served as an isolating mechanism between the two regions by inundating their connection via the lower Ohio River (Walker, 1917).

Some species characteristic of the northern Interior Basin assemblage (e.g., *Lasmigona complanata*, *Proptera alata*) presently range as far south as the Interior Highlands. These may represent

refugial populations that have persisted since glaciation. Johnson (1978) notes that the Interior Highlands were probably a Pleistocene refugium which was a source for recolonization of the upper Mississippi drainages and portions of the Great Lakes drainages (Walker, 1913; van der Schalie, 1945). During the extent of maximum glaciation, the Ohio River may have been unsuitable as a corridor between the Interior Highlands and the Cumberland due to ice, temperature, or silt-load.

Pre- and postglacial channels of the Mississippi and Ohio rivers were quite different from the present. Through Arkansas, the postglacial Mississippi River has flowed west of Crowley's Ridge, skirting the base of the Ozark Plateaus, and occupying portions of the following present drainages: Black, Cache, St. Francis, L'Angeuille, Little, Tyrone, and Arkansas rivers and LaGrue and De-View bayous. The Ohio River flowed through Arkansas, occupying the present channels of the St. Francis and Mississippi rivers, into Louisiana, entering the Mississippi River below the confluences of the Arkansas and Ouachita rivers (Fisk, 1944; Thornbury, 1965). These former channels may explain the presence of species as *Proptera capax*, *Lampsilis higginsii*, *L. orbiculata*, and *Dysnomia* species in the St. Francis, Black, and White rivers' drainages and a possible means of dispersal for some species found in the Ouachitas (e.g. *Cumberlandia*, *L. higginsii*, *L. orbiculata*).

Portions of the Interior Highlands have persisted since the Pre-cambrian (St. Francois Mountains in Missouri), never having been completely base-leveled or entirely inundated (Thornbury, 1965; State of Arkansas, 1974). Due to the age, isolation, and refugial function, an endemic unionid fauna has developed (H. and A. van der Schalie, 1950). These species may have evolved within the region as they share a preference for smaller rivers and headwater situations. Alternatively, these species may represent relict populations of refugial species that were not able to recolonize their former habitat. In contrast to the diverse, endemic Cumberland fauna (Ortmann, 1924; van der Schalie, 1973), the endemic Interior Highlands fauna appears to be composed of only seven species. Three of these are restricted north of the Boston Mountains divide between the White and Arkansas drainages, and two are found only in the Ouachitas (Table 3). Other supposed species have been relegated to synonymy. This may reflect the general trend toward fewer species west of the Mississippi River. Alternatively, the fauna may have been depleted fairly recently. Following the last glacial advance, the Interior Highlands became increasingly arid with desert conditions existing possibly as late as 3000 years ago (State of Arkansas, 1974). This may have had a profound effect upon the unionid fauna, with possible extinctions, necessitating the recolonization of smaller streams and former headwaters.

Species widely distributed through the Interior Basin (e.g., *Ligumia recta*, *Anodonta grandis*) have been affected by the same factors as the other groups discussed, but have been more successful at recolonization. These species have been found throughout most of Arkansas.

The geomorphological history of Arkansas has apparently produced a diverse unionid fauna, that is comparable only to Missouri (60 species, 6 subspecies; Buchanan, personal communication) in numbers of species for states west of the Mississippi River (sufficient data is lacking from Louisiana). Additional studies of the unionacean fauna of Arkansas are necessary to adequately portray the current assemblage of species. The fauna from southeastern Arkansas is poorly known due to the paucity of studies. With water resources development (U.S. Army, 1965) and modification from other sources, the fauna may be considerably reduced before it is totally known.

Table 3. Checklist of Arkansas Unionacea: Synoptic table showing distribution by river drainage.

¹Endemic Interior Highlands species restricted to Ozark Plateaus.²Endemic Interior Highlands species restricted to Ouachita Mountains.³Endemic Interior Highland species.⁴Based on or confirmed by information from John L. Harris (personal communication).

	Little River	Red River	Caddo River	Little Missouri River	Saline River	Ouachita River	Bartholomew Bayou	Arkansas River	St. Francis River	Cache River	Little Red River	Spring River	Black River	North Fork White River	Buffalo River	White River	Illinois River
Cumberlandia monodonta						X											
Fusconaia flava		X	X	X	X	X		X	X		X			X	X	X	X
F. flava undata						X			X		X	X	X	X		X	
F. ebena						X			X		X	X	X	X		X	
F. ozarkensis ¹								?				X	X	X	X	X	
Megalanaia gigantea						?	X	X	X							X	X
Amblema plicata			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Quadrula pustulosa			X		X	X		X	X	X	X	X	X	X	X	X	X
Q. quadrula					X	X			X						X	X	
Q. nodulata					X				X						X	X	
Q. metanerva					X				X			X	X		X	X	
Q. cylindrica					X	X			X		X	X	X	X	X	X	
Tritogonia verrucosa					X	X		X	X	X	X	X	X	X	X	X	X
Plectomerus dombeyanus					X	X	X		X	X		X	X			X	
Cyclonaias tuberculata								X				X	X	X	X	X	
Pleurobema cordatum coccineum					X	X		X			X	X	X	X	X	X	
P. c. catillus						X					X	X	X	X			
P. c. plenum						X			X			X					
P. c. pyramidatum						X	X		X			X	X				
Elliptio dilatatus					X	X			X	X	X	X	X	X	X	X	X
Unionerus tetralasmus						X			X	X			X			X	
Alasmodonta calceolus															X	X	
A. marginata						X					X	X	X	X	X	X	
Lasmsgona costata						X		X			X	X	X	X	X	X	
L. complanata											?			X		X	
Arcidens contrifragosus									X	X			X				
Arkansasia wheeleri ²							X										X
Anodonta grandis								X	X	X	X				X	X	X
A.g. corpulenta								X	X	X	X				X	X	
A. imbecilis									X	X			X	X	X	X	
A. suborbiculata									X			X					X

[illegible]

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MOLLUSCAN COMMUNITIES OF THE WEST FLORIDA SHELF

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The West Florida Shelf (Figure 1) is an area encompassing more than 30,000 square miles of the Eastern Gulf of Mexico, beginning just north of the Florida Keys but including the Dry Tortugas, then extending northward to Cape San Blas. Inshore, the fauna varies from primarily tropical Caribbean species in the south to warm-temperate continental species in the north. Several communities defined by temperature, salinity, and substrate are discernible.

The Dry Tortugas consists of a group of seven small islands in the extreme southeastern Gulf approximately 80 miles west of Key West but separated from the Keys by Rebecca Channel. The fauna consists almost entirely of hardier, more tolerant, shallow water tropical species. Substrate is entirely tropical carbonate and salinities almost always exceed 35 o/oo. The Tortugas are situated somewhat north of the moderating temperatures of the Florida Current, and the fauna is severely reduced in some years by extreme cold fronts from the north. Low salinities from freshwater Everglades run-off and toxicity from southwest Florida red tides have also been implicated in faunal damage.

Farther north, a strong tropical influence is exerted by the Loop Current, which passes on its downward swing over the outer portion of the shelf and occasionally releases eddies of Caribbean water to wash onto the shelf. Certain tropical species are doubtlessly recruited by this means. The Florida Middle Ground, a group of reefs rising to perhaps 20 m below the surface from depths of 30-40 m, provides a unique feature in the northeastern Gulf (Hopkins et al., 1977a, b). Many tropical species characterizing the fauna are rare or absent elsewhere on the West Florida Shelf (Lyons, 1976; Turgeon and Lyons, 1977).

Estuaries dominate the coastline from Cape Sable to Cape San Blas. Vegetation varies from vast mangrove forests in the south to *Spartina-Juncus* marshes in the north, and several species of seagrasses are common throughout the region. Sediments are primarily terrigenous quartz sands, but oyster reefs provide some hard substrate. Salinities vary from near zero to about 34 o/oo and temperatures fluctuate greatly (e.g., Taylor et al., 1970). Macronutrients are generally high. Molluscan diversity is high, especially in seaward portions of estuaries. I have recorded nearly 350 species in Tampa Bay. The southern Ten Thousand Islands and northern Big Bend areas are actually huge estuaries gradu-

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ally merging seaward with offshore shelf communities. However, between these and to the far north, estuaries such as Charlotte Harbor, Tampa Bay, and St. George Sound are separated from the Gulf by a series of barrier islands with sandy, seaward beaches.

At least three vertical zones of faunal distribution occurring seaward from estuaries along the west coast of Florida have become apparent during analysis of material collected during the

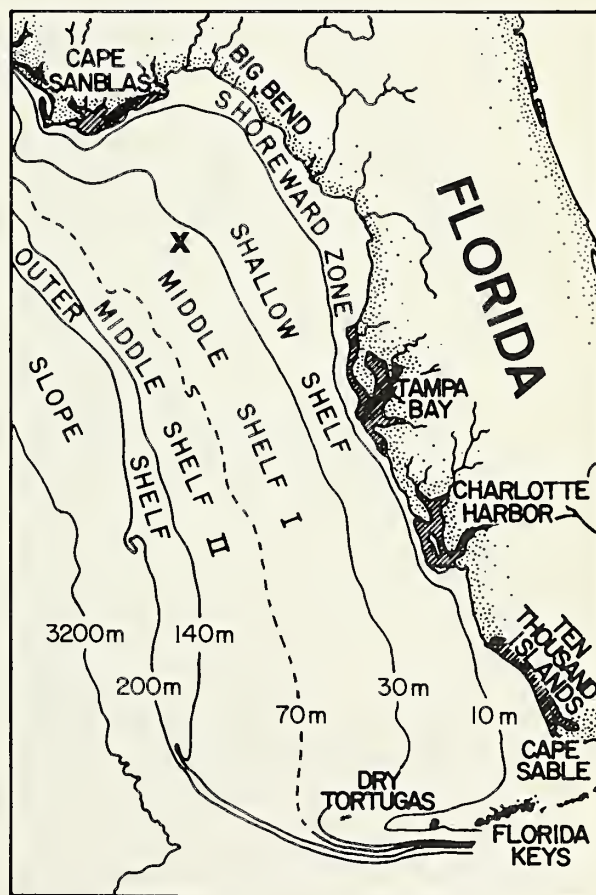


Figure 1. West Florida Shelf, showing subdivisions based upon faunal differences. Florida Middle Ground (x) and major estuaries (slanted shading) indicated.

Hourglass Cruises, a series of some 700+ dredge and trawl tows made by the R/V *Hernan Cortez* at 10 stations in depths from 6 to 73 m during 1965 through 1967 (Joyce and Williams, 1969). Distributional patterns indicating these zones have been discerned in analyses of several groups, including stomatopod, amphipod, isopod, and decapod crustaceans, mollusks, echinoids, and several families of benthic fishes.

The "nearshore," or "shoreward" zone (Lyons and Collard, 1974) occurs from the beach out to depths of approximately 10 m. Sediments are quartz sands, with little hard substrate except that provided by dead shells of large mollusks. Annual temperature fluctuations are considerable (Figure 2), and salinities usually range from 31-34 o/oo (Joyce and Williams, 1969). The fauna is characterized by warm-temperate bivalves. *Donax variabilis* is abundant along beaches. The nearshore fauna is dominated by large and moderately sized, warm-temperate bivalves; such species as *Anadara transversa*, *Noetia ponderosa*, *Atrina rigida*, *A. seminuda*, *Dinocardium robustum*, *Trachycardium egmontianum*, and *Merceneraria campechiensis* are common, as are large, predatory gastropods such as, *Polinices duplicatus*, *Busycon contrarium*, *Fasciolaria hunteria*, and *Pleuroploca gigantea*.

The zone may be characterized as a rich, warm-temperate, upper euryhaline fauna, with obvious relationship to the estuary.

The next zone, designated the shallow shelf (Lyons and Collard, 1974), extends seaward to depths of about 30 or 40 m. Shallow depths permit considerable temperature fluctuations and the area is overlain by a mass of green, coastal water with salinities usually about 35-36 o/oo (Joyce and Williams, 1969). Although quartz sands persist, many warm-temperate Carolinian species have disappeared, and scattered limestone outcroppings provide substrate for a number of submerged, shallow water tropical species. As at Dry Tortugas, these are generally species more tolerant of environmental fluctuation.

At depths of about 30-40 m, the shallow shelf fauna intersects a deeper fauna which has been designated middle shelf (Lyons and Collard, 1974). Near the 30 m isobath, green coastal waters intersect with clearer, less enriched, but more stable blue waters of the middle and outer shelf. Salinities remain around 35 o/oo and temperatures seldom fluctuate more than 3 or 4 degrees from the 20°C isotherm, stabilizing seaward (Figure 2). Sediments are predominantly calcareous except for a small intrusion of quartz sand off Charlotte Harbor, and limestone outcroppings are fairly common. This area, extending from about 40 m to about 140 m, may actually contain two subdivisions, but sufficient data is not available for the area beyond 73 m depths. That two zones may exist is indicated by an apparent center for abundance for many species between 50 and 60 m, and the rare occurrence of some apparently deeper water species at 73 m. Literature records indicating species whose ranges start at about 70 m and extend to about 140 m suggest that a second zone may exist within the middle shelf. The fauna is tropically derived but generally is distributed only along the more environmentally stable outer shelves of the southeastern United States and Gulf of Mexico. Much of it has descended from former Tertiary stocks of the southeastern U.S. As many as 600 to 800 molluscan species may inhabit the middle shelf, such diversity being allowed by the favorable environmental stability of the zone.

Material from commercial specimen shell dredgers indicates a distinctive fauna near the 200 m isobath. Literature records for many species additionally indicate a molluscan assemblage beginning at about 140 m and extending across the 200 m isobath to perhaps as deep as 400 m. To further illustrate these communities, I analyzed species of Muricidae on the West Florida Shelf. Of 27 species of muricids known within the area bounded by the northern Gulf and Florida Keys in depths 70 m or less, 21 species occurred in Hourglass collections. The six "missing" species include two *Dermomurex*, *D. elizabethae* and *D. pauperculus*; the latter was reported in the eastern Gulf by Radwin and D'Attilio (1976) but I have not seen specimens. *Trachypollia nodulosa*, a rock dweller seldom occurring deeper than intertidally in the Keys and Dry Tortugas, is absent to the north, and *Hexaplex fulvescens*, the common large, warm-temperate, continental species, is absent except in the extreme northwest corner of the shelf near Cape San Blas. *Favartia alveata*, a tropical species of the Florida Keys and Dry Tortugas, has been collected at the Florida Middle Ground and may further indicate the more tropical nature of that fauna. The sixth species, *Urosalpinx tampaensis*, is a west Florida endemic so restricted to estuaries that Hourglass sampling began seaward of its range.

Table 1 shows the number of samples containing a particular species at each depth in the Hourglass collections. Greatest incidence of occurrence for each species is underlined. Six species occurred at the 6 m stations, and three of these characterize the nearshore fauna. *Urosalpinx perrugata* is a west Florida endemic

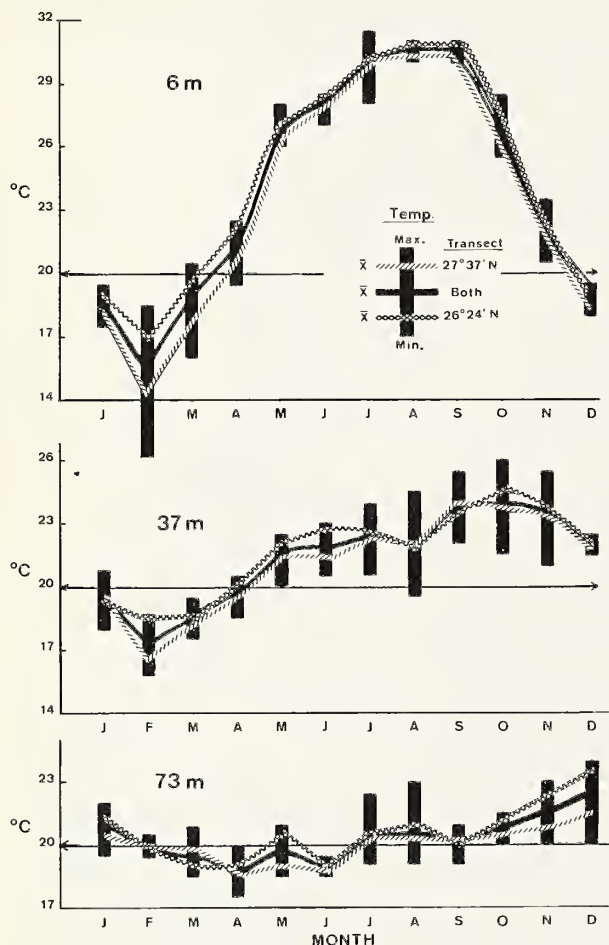


Figure 2. Minimum, maximum, and mean bottom temperatures at three depths (6, 37, and 73 m) each along two transects (26°24'N; 27°37'N) on the West Florida Shelf, August 1965 through November 1967; 37 m station of northern transect sampled bimonthly, all other stations sampled monthly.

(Radwin and D'Attilio, 1976), *Calotrophon ostrearum* occurs only in west Florida and northern Yucatan (Bullock, 1976), and the west Florida range of *Eupleura sulcidentata* was only recently extended to northern Cuba, the Bahamas, and southeast Florida (Lyons, 1977). The remaining three are wide-ranging, common species apparently adaptable to diverse environmental conditions. All six species also occur in west Florida estuaries.

The shallow shelf, consisting of the 18 and 73 m stations, is the area where the well-known shallow water species are most common. *Chicoreus dilectus* and *Favartia cellulosa* are most evident. *Chicoreus pomum*, although captured most often at 6 m, is assigned here on the basis of other collections. It is widespread on the shelf and, with *Chicoreus dilectus* (see Vokes, 1974) and *Calotrophon ostrearum* (see McLean and Emerson, 1970), are the only Gulf muricids to show changes of form with depth. *Murexiella glypta* is a rare species confined to the shallow shelf.

Muricopsis oxytatus is assigned here because of its more shallow occurrence at Dry Tortugas, the Bahamas, and Caribbean islands; it is fairly common at the Florida Middle Ground (Turgeon and Lyons, 1977). Overall, these species comprise a submerged, shallow-water tropical group.

Of sixteen species collected between 37 and 73 m, eleven are restricted to or are characteristic of a middle shelf zone. *Murex cabritii*, *Murexiella levicula*, and *Ocenebra minirosea* are quite common. As indicated in Table 1, ranges of several species may only be beginning at 73 m stations. The possibly subspecific variant of *Chicoreus dilectus* was found only there. *Ocenebra emipowulsi* occurs from 70 to 140 m, and *Poineria stimpsoni*, not collected at 73 m stations, occurs from 90 to 180 m (Radwin and D'Attilio, 1976). These species suggest faunal distinctiveness of the deeper part of the middle shelf.

Murex bellegladeensis, *Murex rubidus*, and *Murex anniae* also

TABLE 1.
MOLLUSCAN ASSEMBLAGES OF THE WEST FLORIDA SHELF
AS EXEMPLIFIED BY SPECIES OF MURICIDAE
IN HOURGLASS COLLECTIONS

Distributional Zone	Samples Containing Species	Hourglass Sampling Depths(m) ¹				
		6	18	37	55	73
1. ESTUARINE/NEARSHORE (0-10 m)						
<i>Urosalpinx perrugata</i>	37	<u>37</u>				
<i>Eupleura sulcidentata</i>	5	<u>5</u>				
<i>Calotrophon ostrearum</i>	14	<u>7</u>	2	3	2	
2. SHALLOW SHELF (10-30 m)						
<i>Chicoreus pomum</i>	69	<u>26</u>	12	15	9	7
<i>Favartia cellulosa</i>	64	<u>11</u>	<u>21</u>	<u>22</u>	5	5
<i>Chicoreus dilectus</i>	99	2	<u>44</u>	<u>36</u>	17	
<i>Murexiella glypta</i>	2		<u>1</u>	1		
<i>Muricopsis oxytatus</i>	2			2		
3. MIDDLE SHELF (30-140 m)						
<i>Acanthotrophon striata</i>	2			2		
<i>Murexiella macgintyi</i>	4			1	<u>3</u>	
<i>Aspella senex</i>	3			1	<u>1</u>	1
<i>Murexsul</i> sp.	2				2	
<i>Murex cabritii</i>	73		1	12	<u>43</u>	17
<i>Murexiella levicula</i>	125			12	<u>81</u>	32
<i>Trachypollia didyma</i>	6				<u>3</u>	3
<i>Ocenebra minirosea</i>	73				<u>36</u>	<u>37</u>
<i>Chicoreus</i> sp. (<i>dilectus</i> ssp.?)	26					<u>26</u>
<i>Ocenebra emipowulsi</i>	1					1
<i>Typhis sowerbii</i>	1					1
4. UNCERTAIN ²						
<i>Murex bellegladeensis</i>						
<i>Murex rubidus</i>						
<i>Murex anniae</i>						
Total Species		6	6	11	11	10

¹6-73 m depths sampled 118, 170, 168, 167, and 113 times, respectively.

²Many immatures not adequately sorted.

occur in the collections but are not enumerated because a large number of juveniles remain to be sorted. The first two were common at several stations, however, and *M. anniae*, at least, is clearly an inhabitant of the middle shelf.

Beginning at 140 m and extending beyond 200 m is a group composed of *Murex tryoni*, *Murexiella hidalgoi*, *Pteropurpura bequaerti*, and *Siratus beauii*. These are joined at about 200 m by *Pterynotus phaneus* and *Paziella pazi*, all apparently constituents of a deep shelf/upper slope assemblage.

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THE NAIAD FAUNA OF THE POWELL RIVER IN VIRGINIA AND TENNESSEE

(Bivalvia: Unionacea)

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The Powell River originates in the coalfields of Wise County in southwestern Virginia and flows southwest through Lee County, Virginia, and Hancock, Claiborne, and Union counties, Tennessee, where it joins the Clinch River in Norris Reservoir (Figure 1). The Powell River is a high gradient stream bordered to the north

by the Cumberland and Stone Mountains and to the south by Wallen Ridge. The Powell River is 200 miles long, and 150 miles remains free-flowing.

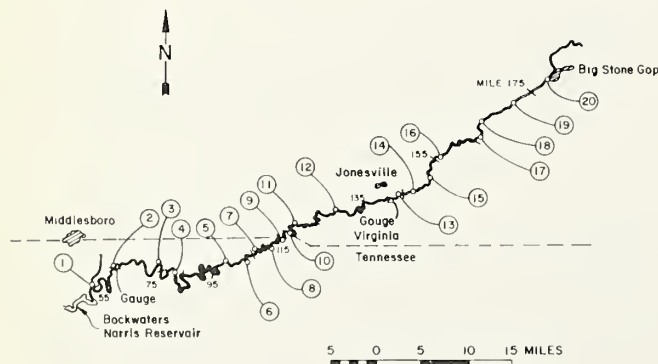
The Powell is one of several major streams which comprise the upper Tennessee River system. These tributary streams have highly diverse aquatic faunas, including over 40 species of freshwater mussels. Some of the freshwater mussel species present in these streams are collectively known as the Cumberlandian fauna because these species are restricted to the southern Appalachian Mountains and the Cumberland Plateau Region. Ortmann (1918) referred to this area as one of the chief centers for freshwater mussel diversity and perhaps the most prolific region in the world for this particular group.

The construction of dams, stream channelization, pollution and silt from strip mines, and coal washing facilities have restricted the Cumberlandian fauna to a few isolated populations in the Powell, Clinch, Duck, and the South, Middle, and North Fork Holston Rivers. Recent collecting in these streams indicates that the richest of these areas are the unimpounded reaches of both the Clinch River above Norris Reservoir (Stansbery 1973, Bates and Dennis 1978) and the Powell River above U.S. Route 25E bridge (river mile 65.2).

This report presents the results of several Tennessee Valley Authority (TVA) surveys that were begun in 1973 as part of the Biological Assessment of Streams Project. Between June 1975 and October 1978, repeated visits to the 20 collecting sites in the Powell (Table 1) have documented the existence of 37 species of mussels still living in this river (Table 2). The most productive area is the reach between river miles 99.2 and 144.3 (sites 5 and 13).

Seven mussel species listed as endangered by the United States Fish and Wildlife Service have been reported from the Powell River. Six of these species (*Conradilla caelata*, *Dromus dromas*, *Quadrula intermedia*, *Quadrula sparsa*, *Fusconaia cu-*

FIGURE 1
POWELL RIVER
MUSSEL SITES
1975-1978



neolus, and *Fusconaia edgariana*) were found living in the river during this survey; however, living *Dysnomia torulosa gubernaculum* were not found. Additionally, the Spiny River Snail, *Io fluvialis* (proposed for listing as endangered was found living in the Powell River in several areas between sites 2 and 16 (Table 2).

Previously published surveys of the Powell River naiad fauna have been limited to those conducted by Adams and Ortmann (both reported in Ortmann 1918). In his paper, Ortmann listed a total of 41 species from 10 sampling sites in the river. Nine of these species were not found during this survey. Six of the nine species (*Alasmidonta minor*, *Lasmigona holstonia*, *Carunculina moesta*, *Pegias fabula*, *Micromya fabalis*, and *Micromya perpur-*

purea) could be considered headwater species and may have been eliminated from the upper Powell River because of siltation. Silt and coal deposits apparently derived from land disturbances and coal mining activity are obvious features of the river above silt 13 and indicate areas with few mussels specimens. The other three species (*Dysnomia lewisi*, *Dysnomia haysiana*, and *Dysnomia torulosa gubernaculum*) were found mainly in the lower Powell River and could have been eliminated by the impoundment of Norris Reservoir. Other recent impacts to the lower part of the river include gravel dredging and bridge construction, both of which could impact the mussel fauna.

Six species not listed by Ortmann were found during this survey. Five of these species (*Quadrula sparsa*, *Quadrula in-*

Table 1
COLLECTING SITES, POWELL RIVER
1975-1978

Sites	Location	River Mile
1	Mouth of Gap Creek above Combs, Claiborne County, Tennessee	54.7
2	Highway 25E bridge crossing, Claiborne County, Tennessee	65.2
3	Jack Nance Island, Claiborne County, Tennessee	73.8
4	Above Cosby Bridge, Claiborne County, Tennessee	79.1
5	Buchanan Ford, Claiborne County, Tennessee	99.2
6	Below Alanthus Hill Bridge, at the mouth of Mulberry Creek, Hancock County, Tennessee	103.3
7	McDowell Shoal, Hancock County, Tennessee	106.6
8	Below Bales Ford, Hancock County, Tennessee	111.7
9	Baldwin Ford, just below Virginia State line, Hancock County, Tennessee	115.5
Tennessee		
Virginia		
10	Fletcher Ford, Lee County, Virginia	117.4
11	Virginia Highway 833 bridge crossing, Lee County, Virginia	120.3
12	Virginia Highway 758 bridge crossing, Flanary Bridge, Lee County, Virginia	130.4
13	Poteet Ford, above Sewell Bridge, Virginia Highway 70, Lee County, Virginia	144.3
14	Cheek Spring Ford, off Virginia Highway 783, Lee County, Virginia	146.8
15	Poteet Ferry Bridge, Virginia Highway 58 bridge crossing, Lee County, Virginia	150.2
16	Above Virginia Highway 421 bridge near Woodway, above mouth of the North Folk Powell River, Lee County, Virginia	156.8
17	Virginia Highway 619 bridge crossing at Camp Creek, Lee County, Virginia	165.7
18	Virginia Highway 58 alternate bridge crossing near Dryden, Lee County, Virginia	166.9
19	2 miles below Olinger, off Virginia Highway 621, Lee County, Virginia	172.3
20	Virginia Highway 58 alternate bridge crossing at Cadet, below Three Forks, Wise County, Virginia	177.8

Table 2. Naiad species which have been collected in the Powell River above Norris Reservoir. Included are the records published by Ortmann (1918) and the results of numerous visits to 20 collecting sites made between 1975 and 1978.

	Ortmann (1918)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mussels:***																					
Cumberlandia monodonta (Say 1829)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ambleria costata (Barnes 1823)	0	-	-	-	x	x	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-
Cyclonaias tuberculata (Rafinesque 1820)	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elipio crassidens (Lamarck 1819)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elipio dilatatus (Rafinesque 1820)	0	-	x	-	-	-	x	x	x	x	x	x	-	x	-	-	-	-	-	-	-
+Fusconia barnesi (Lea 1838)	0	x	x	-	x	x	x	x	-	-	-	-	-	-	-	-	x	-	-	-	-
+Fusconia cuneolus (Lea 1840)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Fusconia edgariana (Lea 1840)	0	-	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
+Fusconia pilaris (Lea 1840)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lastena lata (Rafinesque 1820)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Pleuroberma oviforme (Conrad 1834)	0	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula cylindrica (Say 1817)	0	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-
+Quadrula intermedia (Conrad 1836)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa (Lea 1831)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Quadrula sparsa (Lea 1841)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonia marginata (Say 1818)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alasmidonia minor (Lea 1845)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lasimigona costata (Rafinesque 1820)	0	-	x	-	x	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
+Lasimigona holstonia (Lea 1838)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Pegias fabula (Lea 1836)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus rugosus (Swainson 1822)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Actiononais carinata (Barnes 1823)	0	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	x	-	-	-	-
+Actinonais pectorosa (Conrad 1834)	0	-	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-
Carunculina moesta (Lea 1841)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Conradilla caelata (Conrad 1834)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dromus dromas (Lea 1834)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dysnomia brevidens (Lea 1831)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dysnomia capsaeformis (Lea 1834)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dysnomia haysiana (Lea 1833)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dysnomia lewisi (Walker 1910)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Dysnomia torulosa gubernaculum (Reeve 1865)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dysnomia triquetra (Rafinesque 1820)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis fasciola (Rafinesque 1820)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lampsilis ovata (Say 1817)	0	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodea fragilis (Rafinesque 1820)	0	x	x	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-	-	-	-
Ligumia recta latissima (Rafinesque 1820)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Medionidus conradicus (Lea 1834)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Micromya fabalis (Lea 1831)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Micromya nebulosa (Conrad 1834)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Micromya perpurpurea (Lea 1861)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Micromya vanuxemensis (Lea 1838)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plethobasus cyphus (Rafinesque 1820)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proptera alata (Say 1817)	0	x	x	-	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-
+Ptychobranchius fasciolaris (Rafinesque 1820)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+Ptychobranchius subentum (Say 1825)	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Truncilla truncata (Rafinesque 1820)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Snail:																					
**Io fluviatilis (Say 1825)	-	-	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
+ Cumberlandian Species																					
+ Nomenclature follows Bates and Dennis (1978) including the updating of the names in Ortmann (1918).																					
*** Proposed Endangered O= Ortmann																					

* Endangered

** Cumberlandian Species

*** Nomenclature follows Bates and Dennis (1978) including the updating of the names in Ortmann (1918).

** Proposed Endangered
O = Ortmann

termedia, *Cumberlandia monodonta*, *Lastena lata*, and *Truncilla truncata*) are rare in the Powell, which may account for their absence on Ortmann's list. *Cyclonaias tuberculata*, however, is fairly common in the river and may represent an introduction to the fauna in the last 60 years.

Continued siltation of the river from mining activities could eventually destroy the remaining mussel assemblage. TVA, other Federal agencies, and State agencies in both Tennessee and Virginia are beginning to act to correct this situation. Only time will tell whether these efforts will prevent the loss of this unique and rich freshwater mussel fauna.

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MORPHOMETRIC CHARACTER VARIATION IN *BOONEA IMPRESSA* (Say) AND *B. SEMINUDA* (C.B. Adams) – FAMILY PYRAMIDELLIDAE

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Spiral cord number on the penultimate whorl in the Genus *Boonea*¹ is variable and thus not a good species characteristic (Porter, 1976). Within estuarine populations of *Boonea impressa* (Say, 1822) and *B. seminuda* (C.B. Adams, 1839) the number of cords increases directly in relationship to total shell length; however, in an offshore and Pliocene fossil population of *B. seminuda*, spiral cord numbers are not related to shell length. A possible morphological distinction between estuarine and oceanic populations of *Boonea* is suggested (Porter, 1976).

In the preceeding study only shell length and spiral cord number were discussed; however, other variables of possible taxonomic importance had been recorded: shell width, aperture length, and aperture width. In discussing relative value of systematic characters used in identification of the Genus *Turbonilla*, Powell (1978) suggested that protoconch dimensions and shape of teleoconch whorl number seven have more taxonomic value than aperture shape and spiral cord or axial rib numbers. The possible taxonomic value of the former and the latter measured variables in relationship to species or population differences in the Genus *Boonea* is the subject of this paper.

Data reported here was taken from the same specimens used in Porter (1976). Two measurement series were recorded. The first, containing data collected for but not published in the 1976 publication, has the following variables: shell length, shell width, aperture width, and spiral cord number (Fig. 1; see Porter, 1976 for spiral cord number definition). The second series, as suggested from Powell (1978), includes: shell length, spiral cord number, protoconch height, protoconch width, and the height and width of the sixth whorl (Fig. 1). Regrettably many of the Pliocene fossil shells lacked a sixth teleoconch whorl or measurable protoconch.

The analysis data base includes the above measurements plus selected ratios developed from them. Ratios developed and included in the analysis of the first series are: shell width/length ratio (= shell width/shell length); aperture width/length ratio (= aperture width/aperture length); aperture/shell width ratio (= aperture width/shell width); shell length/number of spiral cords: spi-

ral-cord growth function = $[\text{Log } (8.3 - \text{shell length}) / \text{number of spiral cords}]$; shell-width growth function = $[\text{Log } (8.3 - \text{shell length}) / \text{shell width}]$; aperture-length growth function = $[\text{Log } (8.3 - \text{shell length}) / \text{aperture length}]$; aperture-width growth function = $[\text{Log } (8.3 - \text{shell length}) / \text{aperture width}]$; and inverse functions of each measurement (excluding spiral cord number). Growth functions are calculated "K" values for a von Bertalanffy growth curve (Ricker, 1958) based on the assumption that the divisor in each expression above is an index for age.

Ratios developed and included in the analysis of the second series are: sixth whorl width/height ratio (= sixth whorl width/

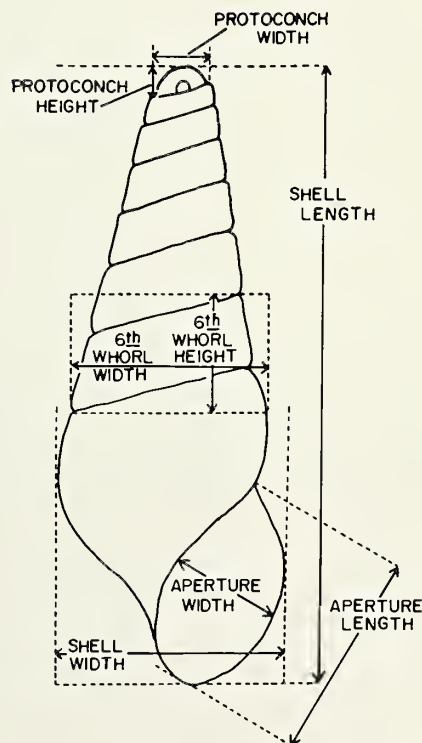


Fig. 1. Diagrammatic illustration of measurements used in *Boonea* study.

sixth whorl height); protoconch width/height ratio (= protoconch width/protoconch height); protoconch/sixth-whorl height ratio (= protoconch height/sixth whorl height); protoconch/sixth-whorl width ratio (= protoconch width/sixth whorl width); spiral-cord growth function (note first series); and inverse functions of each measurement (excluding spiral cord number).

Boonea populations are the same as in Porter (1976). These will henceforth be referred to as Groups 1-4. Group 1 = estuarine *B. impressa* population [epifauna on North Carolina *Crassostrea virginica* (Gmelin) beds]; Group 2 = estuarine *B. seminuda* population [epifauna on *Argopecten irradians* (Lamarck) in North Carolina sounds]; Group 3 = oceanic *B. seminuda* collected from stomachs of the seastar *Astropecten articulatus* (Say)

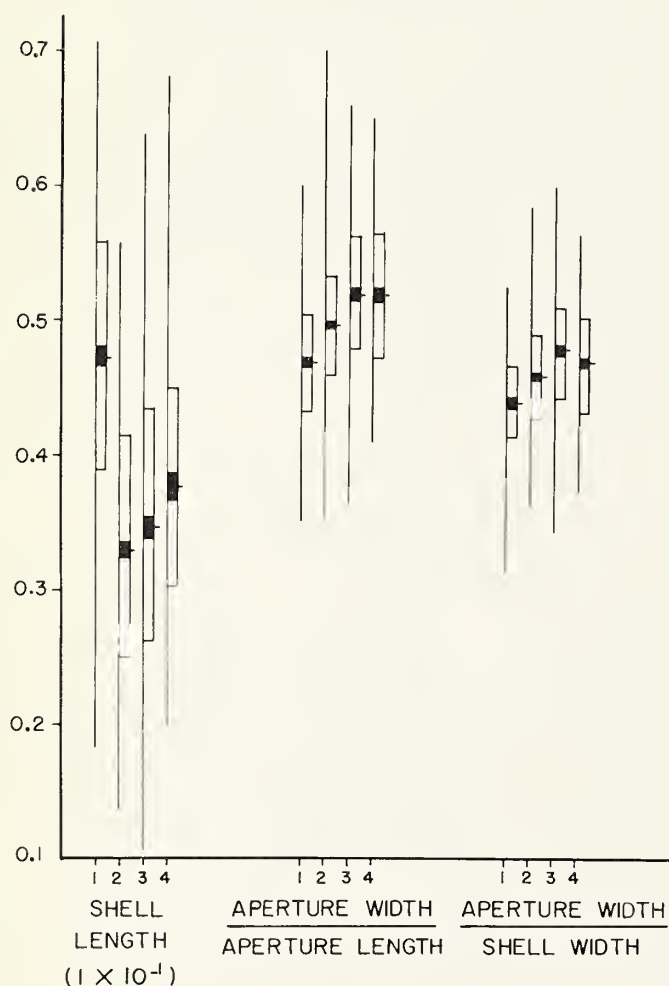


Fig. 2. Variable relationships in *Boonea*, series one data. Population groups indicated by number on horizontal axis. Block diagrams adapted from Hubbs & Hubbs (1953): Vertical lines = range of data; horizontal line = mean length of population; hollow blocks = range of + one standard deviation about the mean; solid blocks = range of + two standard errors about the mean. It is stated that considerable reliance can be placed on the significance between samples, populations in this case, if the solid blocks are slightly separated or do not overlap by more than 33% of the smaller solid block.

which were living among North Carolina populations of *Argopecten gibbus* (Linne) – *B. seminuda* in this case is assumed to have been epifauna on *Argopecten gibbus* (Wells, et al, 1964); Group 4 = Pliocene-age *B. seminuda* from a Neuse River, NC strata, found among fossil *Crepidula fornicata* (Linne).

Data analysis was achieved using SAS (Barr, Goodnight, Sall, and Helwig, 1976), University of North Carolina Computation Center, IBM 360/370 system. SAS procedures – MEANS, PLOT, and DISCRIM calculated basic statistics, plotted pertinent graphs (Figs. 2-4 were not plotted by SAS), and performed discriminant analysis.

Discriminant analysis was used to test the hypothesis that it was possible through use of the variable data base to separate the *Boonea* populations in this study from each other and gain knowledge of their interrelationships. Sokal and Rohlf (1969) discussed the value of discriminant function analysis in separating molluscan populations; there have been a number of papers since where the analysis has been used to separate molluscan populations, species and sexual characteristics.

ANALYSIS OF FIRST SERIES

Correlation coefficient matrix assessment of each population group (discriminant analysis data) indicated that the only variables not correlated with shell length were "aperture width/length ratio" (population group coefficients ranged from -0.1515 to 0.1839) and "aperture width/shell width ratio" (population group coefficients ranged from 0.1432 to 0.3303). All other variables except spiral cord number were highly correlated with shell length; for example, "shell width/length ratio" had population group correlation coefficients ranging from -0.7820 to -0.8428. Spiral cord number correlation coefficients were not consistently correlated (Group 1 = 0.5230; Group 2 = 0.6995; Group 3 = 0.3906; and Group 4 = 0.4926) as also suggested in Porter (1976) data.

Analysis of variables not correlated with length (Fig. 2) show that mean values of population groups 1 and 2 (estuarine habitat) differ significantly from all other population groups and that population groups 3 and 4 (oceanic habitat) differ not as much from each other as they do from groups 1 and 2, further suggesting morphometric distinctiveness between estuarine and oceanic populations.

No variable combination was found having a discriminant classification criteria which, when used to reclassify data, classified a high percentage into the correct group (see Tables 1 and 2 for typical examples). Analysis excluding group 1 (*B. impressa* population) but with the same variables (note Table 2), attempting to classify by restricting analysis to individuals of one species, produced little improvement in percentage correct classification (Table 3). Similar analyses without group 1 data and using other variable combinations had corresponding results.

ANALYSIS OF SECOND SERIES

Assessment of group correlation coefficient matrices indicated that the only ratio correlated with length was "spiral-cord growth function" (population group correlations ranged -0.9845 to -0.9418); group length related coefficients with all other variables and their ratios were not correlated and ranged between -0.04653 and 0.4486.

Data analysis indicated that: with sixth whorl heights and sixth whorl widths, population groups 1 and 2 (estuarine habitat) differed significantly from each other and from all other population groups, but no difference was present between 3 and 4

(oceanic habitat) (Fig. 3); with the "sixth whorl width/height ratio", no significant differences occurred between any of the population groups (Fig. 3); with protoconch height, population groups 1 and 2 were significantly different from 3 and 4 (Fig. 4); with protoconch width, population group differences between each other were erratic and showed no pattern (Fig. 4); with "protoconch width/height ratio", all population groups analyzed, differed significantly from each other (Fig. 4); and with "protoconch/sixth-whorl height and width ratio" (Fig. 4), population groups 1, 2, and 3 were all significantly different from each other but group 4 was not significantly different from groups 2 and 3. These analyses suggested that some variables exhibited significant differences between all populations and that those from an estuarine habitat were closer related to each other than to those from an oceanic habitat. Several variables have insignificant population differences. Most variables though were suggestive that the *B. seminuda* populations were closer related to each other than they were to the estuarine *B. impressa* population and that frequently no significant difference was exhibited between the two oceanic *B. seminuda* populations.

The data base for the discriminant analysis in this series consisted primarily of variables not correlated with length as opposed to that in the first series. Early analysis done without group 4 reclassified a high percentage of data by group correctly (Table 4); however, when the same analysis was executed using all four groups and the same variables, only a small percentage of group 4 was reclassified as belonging in group 4 (Table 5). Later analysis excluding spiral cord related variables enabled a classification criteria to be developed which reclassified a high percentage of the specimens into the correct group (Table 6). Here the close

relationship of group 4 to group 3 may be suggested by the percent of group 4 miss-reclassified into group 3 (23.08%). Variable included in this classification criteria were: shell length; sixth-whorl height; sixth-whorl width; protoconch height; protoconch width; sixth-whorl width/height ratio; protoconch width/height ratio; protoconch/sixth whorl height ratio; protoconch/sixth-whorl width ratio; 1/sixth-whorl height; 1/sixth-whorl width; 1/protoconch height; and 1/protoconch width.

CONCLUSIONS

1. It is possible in the Genus *Boonea* through use of discriminant analysis of shell characteristics not correlated with total shell length to set up a discriminant classification criteria separating species and populations within a species. In such, useful morphometric characteristics are: shell length plus widths and heights of both the protoconch and the sixth whorl.

2. The North Carolina offshore population of *B. seminuda* is not as closely related morphologically to the estuarine population of *B. impressa* as is the estuarine population of *B. seminuda*.

3. The North Carolina Pliocene fossil population of *B. seminuda*, while separable as a distinct population from the other populations, seems closest related to the North Carolina offshore *B. seminuda* population.

4. While it is possible to separate the above populations by statistical analyses using specific morphometric variables and their ratios, the overlap of data within these variables between populations prevents their use in field identification of populations.

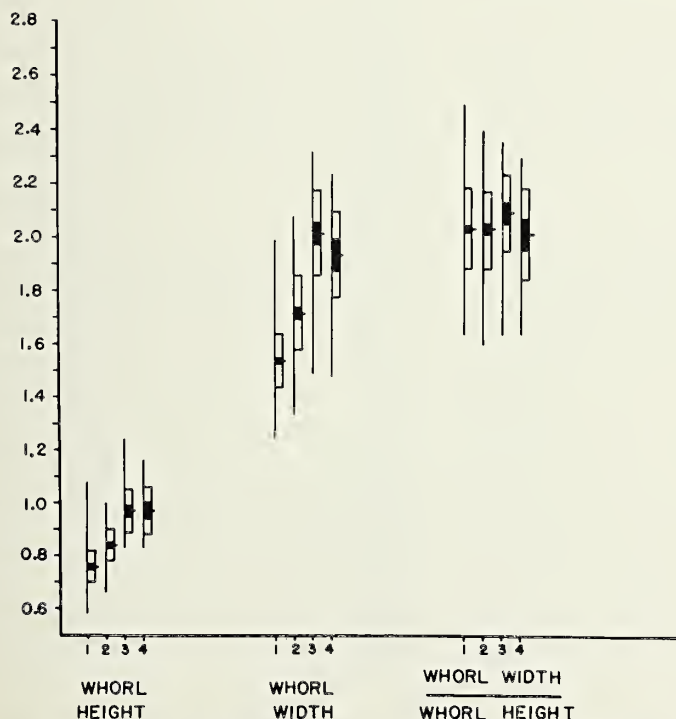


Fig. 3. Variable relationships in *Boonea*, series two data. See Fig. 2 for graph description.

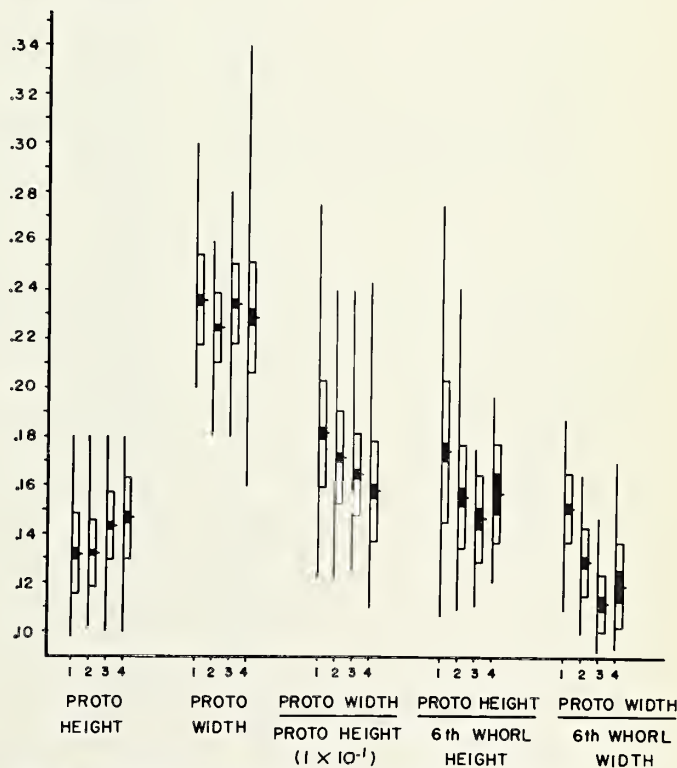


Fig. 4. Variable relationships in *Boonea*, series two data. See Fig. 2 for graph description.

TABLE 1.

PERCENT OBSERVATIONS SERIES ONE DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.

VARIABLES: shell length; shell width/length ratio; aperture width/length ratio; aperture/shell length ratio; number of spiral cords; shell length/number of spiral cords; spiri-cord growth function; shell-width growth function; aperture-length growth function; aperture-width growth function; aperture/shell width ratio; number of spiral cords; shell length/number of spiral cords; spiri-cord growth function; shell-width growth function; aperture-length growth function; aperture-width growth function; aperture/shell width ratio; number of observations = ().

GROUP	1	2	3	4	TOTAL
1	83.57 (478)	12.59 (72)	0.87 (5)	2.97 (17)	100.00 (572)
2	9.99 (80)	64.29 (515)	2.62 (21)	23.10 (185)	100.00 (801)
3	4.26 (28)	26.18 (172)	19.33 (127)	50.23 (330)	100.00 (657)
4	2.30 (7)	18.09 (55)	6.58 (20)	73.03 (222)	100.00 (304)
TOTAL PERCENT	25.41 (593)	34.88 (814)	7.41 (173)	32.31 (754)	100.00 (2334)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:

TEST CHI-SQUARE VALUE = 8129.7871 with 198 DF PROB > CHI-SQ. = 0.001

TABLE 2.

PERCENT OBSERVATIONS SERIES ONE DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.

VARIABLES: shell length; shell width; aperture length; shell width/length ratio; aperture width/length ratio; aperture/shell length ratio; aperture/shell width ratio; shell-width growth function; aperture-length growth function; 1/shell length; 1/shell width; 1/aperture length; and 1/aperture width. Number of observations = ().

GROUP	1	2	3	4	TOTAL
1	84.97 (486)	7.69 (44)	0.35 (2)	6.99 (40)	100.00 (572)
2	12.23 (97)	36.33 (291)	4.62 (37)	46.82 (375)	100.00 (801)
3	4.41 (29)	16.41 (108)	13.53 (89)	65.65 (432)	100.00 (658)
4	3.95 (12)	8.88 (26)	4.28 (13)	83.22 (253)	100.00 (304)
TOTAL PERCENT	26.77 (625)	20.09 (469)	6.04 (141)	47.11 (1100)	100.00 (2335)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:

TEST CHI-SQUARE VALUE = 16711.3690 with 360 DF PROB > CHI-SQ. = 0.0001

TABLE 3.

PERCENT OBSERVATIONS SERIES ONE DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.

VARIABLES: shell length; aperture length; shell width; aperture width; shell width/length ratio; aperture/shell length ratio; aperture/shell width ratio; shell-width growth function; aperture-length growth function; aperture-width growth function; 1/shell length; 1/shell width; 1/aperture length; and 1/aperture width. Number of observations = ().

GROUP	2	3	4	TOTAL
2	47.32 (379)	4.62 (37)	48.06 (385)	100.00 (801)
3	18.69 (123)	14.59 (96)	66.72 (439)	100.00 (658)
4	10.20 (31)	4.28 (13)	85.53 (260)	100.00 (304)
TOTAL PERCENT	30.23 (533)	8.28 (416)	61.49 (1084)	100.00 (1763)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:

TEST CHI-SQUARE VALUE = 6870.5854 with 240 DF PROB > CHI-SQ. = 0.001

TABLE 4.
PERCENT OBSERVATIONS SERIES ONE DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.
VARIABLES: sixth-whorl width/height ratio; protoconch width/height ratio; protoconch sixth-whorl height ratio; and spiral-cord growth function. Number of observations = ().

GROUP	1	2	3	TOTAL
1	82.67 (229)	15.88 (44)	1.44 (4)	100.00 (277)
2	20.89 (33)	60.13 (95)	18.99 (30)	100.00 (158)
3	1.64 (1)	24.59 (15)	73.77 (45)	100.00 (61)
TOTAL PERCENT	53.02 (263)	31.05 (154)	15.93 (79)	100.00 (496)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:
TEST CHI-SQUARE VALUE = 222.9843 WITH 30 DF PROB > CHI-SQ = 0.001

TABLE 5.
PERCENT OBSERVATIONS SERIES ONE DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.
VARIABLES: sixth-whorl width/height ratio; protoconch width/height ratio; protoconch sixth-whorl height ratio; and spiral-cord growth function. Number of observations = ().

GROUP	1	2	3	4	TOTAL
1	86.23 (238)	12.32 (34)	1.45 (4)	0.00 (0)	100.00 (276)
2	22.15 (35)	56.96 (90)	18.99 (30)	1.90 (3)	100.00 (158)
3	1.64 (1)	21.31 (13)	70.49 (43)	6.56 (4)	100.00 (61)
4	19.23 (5)	23.08 (6)	34.62 (9)	23.08 (6)	100.00 (26)
TOTAL PERCENT	53.55 (279)	27.45 (143)	16.51 (86)	2.50 (13)	100.00 (521)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:
TEST CHI-SQUARE VALUE = 237.4631 WITH 45 DF PROB > CHI-SQ = 0.001

TABLE 6.
PERCENT OBSERVATIONS SERIES TWO DATA CLASSIFIED INTO GROUP BY DISCRIMINANT ANALYSIS.
VARIABLES: shell length; sixth-whorl height; sixth-whorl width; protoconch height; protoconch width; sixth-whorl width/height ratio; protoconch width/height ratio; protoconch sixth-whorl height ratio; and 1/sixth-whorl width; 1/sixth-whorl height; 1/sixth-whorl width; 1/protoconch height; and 1/protoconch width. Number of observations = ().

GROUP	1	2	3	4	TOTAL
1	88.04 (243)	11.23 (31)	0.36 (1)	0.36 (1)	100.00 (276)
2	13.84 (22)	72.33 (115)	11.32 (18)	2.52 (4)	100.00 (159)
3	0.00 (0)	13.11 (8)	78.69 (48)	8.20 (5)	100.00 (61)
4	0.00 (0)	7.69 (2)	23.08 (6)	69.23 (18)	100.00 (26)
TOTAL PERCENT	50.77 (265)	29.89 (156)	13.98 (73)	5.36 (28)	100.00 (522)

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES:
TEST CHI-SQUARE VALUE = 237.4631 WITH 45 DF PROB > CHI-SQ = 0.001

ACKNOWLEDGEMENTS

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- ¹*Boonea impressa* (Say, 1922) = *Odostomia impressa*; *Borrea seminuda* (C.B. Adams, 1839) = *Odostomia seminuda* – note Robertson (1978).

POPULATION DYNAMICS OF MOLLUSCS IN
A SEAGRASS BED SURROUNDING A DREDGED
MATERIAL ISLAND, UPPER LAGUNA MADRE, TEXAS

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INTRODUCTION

The upper Laguna Madre along the south Texas coast is a clear, shallow, hypersaline lagoon that supports extensive seagrass beds. These floral communities sustain a rich, diverse fauna that utilized the grass beds for food, protection, habitat, and spawning ground. They provide an excellent substratum for a diverse and abundant population of molluscs (Simmons 1957). The purpose of this study is to determine the seasonal occurrence of the molluscan populations within a localized grass bed surrounding a dredged material island in the upper Laguna Madre, Texas.

The flora and fauna of the bays and lagoons of the Texas coast have been well documented. Hedgpeth (1967) summarized work done in and around the Laguna Madre. Simmons (1957) and Breuer (1962) completed ecological surveys of the Laguna Madre. They established the presence of five species of spermatophytes dominated by *Halodule beaudettei* Ascherson. The molluscan fauna was characterized by the bivalves *Anomalocardia auberiana* (Orbigny), *Mulinia lateralis* (Say) and the gastropod *Bittium varium* (Pfeiffer). A series of ecological surveys in the vicinity of Pita Island revealed gastropods to be scarce (Hildebrand and King 1974, 1975, and 1976). *Cerithium lutosum* (Adams) and *B. varium* were the only species collected, and these were confined to the submerged meadows. Of the bivalves taken, *M. lateralis* was the most abundant. *Amygdalum papyria* (Conrad) was second in abundance and found primarily attached to the base of *H. beaudettei*. In 1976, Hildebrand and King noted that as salinities rose in the upper Laguna Madre, *A. auberiana* became the most abundant bivalve, and *Aequipecten irradians amplicostatus* (Dall) was second. A decline in abundance of nearly every species of molluscs was reported for 1977-1978 (Hildebrand and King 1979). They recorded 9 species of bivalves

and 5 species of gastropods. The most abundant species was *Macra fragilis* Gmelin.

STUDY AREA

The upper Laguna Madre is a shallow coastal lagoon located on the Texas Gulf Coast south of Corpus Christi Bay. It is separated from the Gulf of Mexico by a narrow barrier island, Padre Island. The lagoon is approximately 208 km long with an average depth of 0.75 m. The Intracoastal Waterway, completed in 1948, bisects the lagoon. It averages approximately 3.66 m deep. Most of the spoil removed while dredging the canal forms a series of small islands along the canal banks.

Seagrasses form the dominant benthic habitat of the upper Laguna Madre. In order of occurrence the spermatophytes found within the shallow waters of the lagoon are *Halodule beaudettei* Ascherson (the dominant species), *Ruppia maritima* Linne, and *Halophila engelmannii* Ascherson. The study is limited to the submerged grass beds surrounding Corpus Christi State University's dredged material island (97°18'51" N; 27°32'27" W), 9.6 km south of Kennedy Causeway.

METHODS AND MATERIALS

The study area was sampled monthly from April 1977 to April 1978. Two transects were run perpendicular to the Intracoastal Waterway extending east and west on either side of the dredged material island. Stations were established along the transects at 15 m intervals from the western shoreline of the dredged material island or edge of the grass bed to the Intracoastal Waterway and from the eastern shoreline to approximately 200 m east of the dredged material island. In addition to these stations, two stations were located to the north and south of the dredged material island midway between adjacent islands. 52 benthic samples were taken monthly.

A modified posthole-digger (15 cm X 15 cm X 15 cm) was used to obtain a uniform sample of vegetation, sediment, and associated fauna. Two random samples were taken at each station. In the field, the samples were sieved through a 500 μ sieve (U.S. Standard Sieve No. 35), then placed in labeled plastic bags con-

taining 10% formalin treated with Rose Bengal, a staining agent specific for living material, used to aid the sorting of live material.

Physical parameters were measured during each sampling period by the following methods. Salinity was read *in situ* with an A.O. Goldberg Refractometer and recorded in parts per thousand. Water temperature, was measured with a standard centigrade thermometer. A meter stick was used to measure water depth at each station. Sediment samples were taken at 45 m intervals along the transects and at the north and south stations. Each sediment sample was wet sieved with fresh water through a 62 μ sieve. After drying and weighing, the sample was then dry sieved through a standard sieve series. The sediments remaining in each sieve were weighed to calculate the weight percent of each sediment fraction. The silts and clay fractions were determined by pipetting.

RESULTS AND DISCUSSION

In the present study 44 species of molluscs representing 25 families were identified (Table 1). 16 of the 44 species were collected throughout the sampling period. These represented 91.33% of the molluscan population by numbers. Transect A was dominated by 6 of the 16 species, accounting for 14% of the observed species density. The most abundant molluscs were *Amygdalum papyria* (Conrad) followed by *Tellina texana* Dall. 10 of the 16 species dominated Transect B and accounted for 77% of the population by number. *Mysella planulata* (Stimpson) was the most abundant, *Crepidula maculosa* Conrad was second. The species endemic to a particular transect were not collected throughout the sampling period. Transect A had the highest species diversity: *Vitrinella* cf. *helicoidea* (Adams), *Anachis obesa* (Adams), *Aligena texasiana* Harry and *Anadra transversa* (Say). *Noetia ponderosa* (Say), only occurred along Transect B.

The numbers of individuals and species of molluscs fluctuate seasonally. For both transects, the number of individuals increased through the spring to a peak in the summer. This was followed, after a period of reduced numbers of species, by a major increase in the winter. The summer population was generally uniformly distributed along the transects from shore to channel. The highest density was recorded 105 m from the shorelines for both transects. In the fall and winter there was a shift in population density to the deeper waters of the channels.

Seasonally peaks in numbers of individuals and numbers of species usually occurred during summer and winter periods. The summer peak was reached during July and August, when water temperatures averaged 33.5°C and salinity averaged 37.5 ppt. Species density averaged 22% and diversity averaged 70.45%. During July and August, a small number of adults and many juveniles were collected among the luxuriant seagrass beds of *Halodule beaudettei* and *Halophila engelmannii*. *H. beaudettei* showed average counts of 100, with lengths averaging 13 cm. *H. engelmannii* averaged 62 per count, with an average length of 4 cm.

The cold weather peak, consisting of a large population of adult molluscs was reached in February and March. The water temperatures were a low 8°C and 20°C, respectively, and salinity averaged 32 ppt. Species density averaged 7% and diversity averaged 74%. Following a die back of seagrass, the averaged count for *H. beaudettei* was 18 with lengths averaging 6 cm; *H. engelmannii* averaged 16, with a 2 cm average length.

This double peak trend was similar to that which Livingston (1976) recorded in a study of a north Florida estuary. Parker (1967), and Zimmerman and Chaney (1969) considered temp-

erature and salinity important in regulation invertebrate populations. The rise and decline of this population may be a reflection of a normal seasonal variation due to temperature, and may not be directly related to salinity.

In summary, a marked seasonal cycle is apparent for numbers of individuals in the study area. The cycle peaks both in summer and in the cold weather months of February and March, and the smallest numbers are present in the fall.

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TABLE 1. Species of molluscs collected in a seagrass bed surrounding a dredged material island, upper Laguna Madre, Texas.

SPECIES	SPECIES
VITRINELLIDAE	ARCIDAE
<i>Vitrinella</i> cf. <i>helicoidea</i>	<i>Anadra transversa</i>
<i>Solariorbis infracarinata</i>	NOETIIDAE
CAECIDAE	<i>Noetia ponderosa</i>
<i>Caecum pulchellum</i>	MYTILIDAE
CERITHIIDAE	<i>Brachidontes exustus</i>
<i>Cerithium lutosum</i>	<i>Amygdalum papyria</i>
<i>C. pliculosa</i>	PECTINIDAE
<i>Diastoma varium</i>	<i>Argopecten irradians</i>
CERITHIOPSIDAE	<i>amplicostatus</i>
<i>Cerithiopsis greeni</i>	UNGULINIDAE
TRIPHORIDAE	<i>Diplondonta semiaspera</i>
<i>Triphora perversa</i>	KELLIIDAE
EPITONIIDAE	<i>Mysella planulata</i>
<i>Epitonium rupicola</i>	SPORTELLIDAE
CALYPTRAEIDAE	<i>Aligena texasiana</i>
<i>Crepidula maculosa</i>	CARDIIDAE
COLUMBELLIDAE	<i>Laevicardium mortoni</i>
<i>Anachis avara</i>	MACTRIDAE
<i>A. obesa</i>	<i>Mactra fragilis</i>
<i>Mitrella lunata</i>	<i>Mulinia lateralis</i>
NASSARIIDAE	SOLENIDAE
<i>Nassarius vibex</i>	<i>Ensis minor</i>
MARGINELLIDAE	TELLINIDAE
<i>Pyrgocythara plicosa</i>	<i>Macoma tenta</i>
PYRAMIDELLIDAE	<i>Tellina tampaensis</i>
<i>Odostomia impressa</i>	<i>T. texana</i>
<i>O. cf. livida</i>	SOLECURTIDAE
<i>Turbonilla cf. portoricana</i>	<i>Tagelus divinus</i>
ACTEONIDAE	<i>T. plebeius</i>
<i>Rictaxis? punctostriatus</i>	SEMELIDAE
<i>Acteocina canaliculata</i>	<i>Cumingia tellinoides</i>
BULLIDAE	VENERIDAE
<i>Bulla striata</i>	<i>Anomalocardia auberiana</i>
ATYIDAE	<i>Chione cancellata</i>
<i>Haminoea antillarum</i>	LYONSIIDAE
<i>H. succinea</i>	<i>Lyonsia hyalina</i>

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SOUTH AMERICAN PARASITIC MITE GENUS *ATACELLA*
(ARTHROPODA: ACARI: UNIONICOLIDAE) IN
NORTH AMERICAN FRESH-WATER MUSSELS
(BIVALVIA: UNIONOIDA: UNIONACEA AND MUTELACEA)

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Most species-group taxa of unionicolid mites that infest specific sites within the branchial chambers of fresh-water mussels have been placed in the cosmopolitan genus *Unionicola*. The large, intrabranchial unionicolid mussel parasites that are placed in the possibly monotypic genus *Najadicola*, are now known to be found in North America (including Mexico) and Southeast Asia (M.F. Vidrine, unpublished). *Atacella*, the only other unionicolid genus known to infest unionoid mussels, has been reported only from mycetopodid mutelacean and hyriid unionacean mussels in a small portion of southeastern South America (Fig. 1). Our data indicate that mites that are consistent with Cook's (1974) concept of the genus *Atacella* also occur in southern United States and northern Mexico (Fig. 1), in mycetopodid and unionid mussels, and that the range of *Atacella* possibly extends continuously in the Americas.

The reported differences between nominal *Atacella* and *Unionicola* lie primarily in the shape and degree of sclerotization of the palpi, and in the degree of separation between the third and fourth coxal plates (epimera): *Atacella* has flat palpi whose venters are weakly sclerotized, and its third and fourth coxal plates are completely separated by a suture; *Unionicola* has subcylindrical palpi whose venters are strongly sclerotized, and its third and fourth coxal plates are incompletely separated by a suture (Cook 1974). However, an ongoing, comprehensive study of the unionicolid mite parasites of North American unionacean mussels (M.F. Vidrine, unpublished) has revealed that *U. stricta* (Wolcott 1898) [known only from the mussel *Uniomereus tetralasmus* (Say 1831), concept of Johnson, 1970)] (Vidrine 1973, 1974) and those mites in the complex *U. tupara* Mitchell and Wilson 1965 [known only from the unionid genera *Amblema*, *Megaloniais*, *Plectomerus*, and *Elliptoideus* (Vidrine 1979)] are intermediate in terms of the features that are presently published (Cook, 1974) as the differences between *Unionicola* and *Atacella*. Therefore, even though *Atacella* probably represents a distinct clade within the Unionicolidae, the morphological differences between *Atacella* and *Unionicola* are not trenchantly defined.

Table 1 summarizes the previously reported incidence of *Atacella* in unionoid mussels. All these records are from Paraguay, Uruguay, southeastern Brazil, and northeastern Argentina from hosts in the mycetopodid genus *Anodontites* and the hyriid genera *Castalina* and *Diplodon*. At least two species of *Atacella*, *A. perforata* (Koenike 1890) and *A. clathrata* Lundblad 1937, infest both mutelacean and unionacean mussels in South America.

Table 2 summarizes our new locality and incidence records of *Atacella*, from the southeastern United States and northern Mexico. These records are from hosts in the mycetopodid genus



Fig. 1. Known geographic distribution of *Atacella*, s.l. in the Americas. Closed circles (•) represent locality records.

Anodontites (in Mexico) and a series of unionid taxa (*Popenaias*, "Nephronaias", "Disconaias", and *Carunculina*) in the United States and Mexico. The *Atacella* taxa found by us in the Mexican *Anodontites* appear to be conspecific with those reported to infest *Anodontites* in South America; this supports the hypothesis of a range of *Atacella* that is continuous from the United States to Argentina. *Atacella* infesting unionid taxa, however, are different from those reported from South American unionoids. Two of these mite entities are undescribed and appear to be closely related to each other: *Atacella* (A.) sp. nov. Type I (found in the Rio Grande and Panuco River systems) and *Atacella* (A.) sp. nov. Type II (found in the Panuco River system). *Atacella* (A.) sp. nov. Type I infests unionid genera that are referable (by inference) to the Davis, et. al. (1978) tribes Lampsilini ("Disconaias") and Elliptionini (*Popenaias* and "Nephronaias"); *Atacella* (A.) sp. nov. Type II was found only in nominal *Popenaias* in the Panuco River system. A third entity, *Atacella* (A.) sp. nov. Type III,

referred to as *Unionicola latipalpa*, a manuscript name, has been described in an unpublished thesis (Dobson, 1966) from *Carunculina parva* (Barnes 1823) in the Apalachicola province (Suwannee River to the Escambia River drainages) of Alabama and Florida. This entity was also found in the same host in the Navasota River (Brazos River system) (Calnan, 1976; referred to as *Unionicola* sp. "III") and other eastern and central Texas locations (M.F. Vidrine, unpublished). Despite the examination of a large number (60 lots) of *Carunculina* from the area between eastern Texas and Alabama, no *Atacella* (A.) sp. nov. Type III were found. In our opinion, the data do not support any explanation of the apparent interruption in the range of the latter.

In about 175 species (and about 15,000 specimens) of mussels examined thus far in North America from about 475 stations, *Atacella* has not been found in any mussel species or locality other than those mentioned above. Although data are too scanty to permit discussion of the specificities of other *Atacella* for their

Table 1. Previous records of co-occurrence of *Atacella* with mussel hosts. Mussel taxa are indented to the right, under the mite taxa. All names are literary; they were not verified by the authors.

<i>Atacella</i> (A.) <i>fissipes</i> (Koenike 1891)	<i>Diplodon charuanus</i> (D'Orbigny 1835)
<i>Anodontites patagonicus</i> (Lamarck 1819)	Argentina – Rosso de Ferradas, 1976
Brazil – Koenike, 1891	<i>Atacella</i> (A.) <i>entremianensis</i> Rosso de Ferradas 1976
Paraguay – Lundblad, 1937, 1938 and 1941	<i>Anodontites trapesialis spixii</i> (D'Orbigny 1835)
<i>Anodontites trapesialis susannae</i> (Gray 1834)	Argentina – Rosso de Ferradas, 1976
Argentina – Rosso de Ferradas, 1976	<i>Atacella</i> (<i>Atacellides</i>) <i>rugosus</i> (Koenike 1890)
<i>Atacella</i> (A.) <i>perforata</i> (Koenike 1890)	<i>Anodontites p. patagonicus</i> (Lamarck 1819)
<i>Anodontites patagonicus</i> (Lamarck 1819)	Brazil – Koenike, 1890
Brazil – Koenike, 1890	Uruguay – Caches and Mane-Garzon, 1973
Uruguay – Caches and Mane-Garzon, 1973	<i>Atacella</i> (<i>Atacellides</i>) <i>schubarti</i> Viets 1954
<i>Diplodon delodontus pilbsryi</i> Marshall 1928	<i>Diplodon delodontus expansus</i> (Kuster 1856)
Uruguay – Caches and Mane-Garzon, 1973	Brazil – Viets, 1954
<i>Anodontites trapesialis spixii</i> (D'Orbigny 1835)	<i>Atacella</i> (A.) <i>subrecta</i> Caches and Mane-Garzon 1973
Argentina – Rosso de Ferradas, 1976	<i>Anodontites p. patagonicus</i> (Lamarck 1819)
<i>Atacella</i> (A.) <i>clathrata</i> Lundblad 1937	Uruguay – Caches and Mane-Garzon, 1973
<i>Anodontites</i> sp.	<i>Atacella</i> (A.) <i>gigantea</i> Caches and Mane-Garzon 1973
Brazil – Lundblad, 1937, 1941 and 1942	<i>Anodontites p. patagonicus</i> (Lamarck 1819)
<i>Anodontites obtusus lucidus</i> (D'Orbigny 1835)	Uruguay – Caches and Mane-Garzon, 1973
<i>Anodontites trapesialis spixii</i> (D'Orbigny 1835)	<i>Atacella</i> (<i>Polytacidus</i>) <i>prominens</i> (Koenike 1914)
<i>Diplodon rhuacoicus</i> (D'Orbigny 1835)	<i>Catalina nehringi</i> von Ihering 1891
	Brazil – Koenike, 1914

Table 2. New records of co-occurrence of *Atacella* with mussel hosts. Mite taxa are indented to the right, under the mussel taxa. All mite taxa are concepts of M.F. Vidrine. All mussel taxa are the concepts of D.J. Berezina.

Mutellacea	<i>Popenaias</i> ?sp. nov. (= <i>P. popei</i> of authors)
Mycetopodidae	<i>Atacella</i> (A.) sp. nov. Type II
<i>Anodontitinae</i> (sensu Parodiz and Bonetto, 1963)	Panuco River system, Mexico
<i>Anodontites trapesialis glaucus</i> (Valenciennes 1833)	<i>Popenaias metallica ganina</i> (Pilsbry 1909)
<i>Atacella</i> (A.) <i>fissipes</i> (Koenike 1891)	<i>Atacella</i> (A.) sp. nov. Type II
Northwestern Mexico	"Nephronaias" sp.
<i>Atacella</i> (A.) <i>perforata</i> (Koenike 1890)	<i>Atacella</i> (A.) sp. nov. Type I
Panuco River system, Mexico	Rio Huichihuayan, Panuco River system, Mexico
<i>Atacella</i> (A.) <i>entremianensis</i> Rosso de Ferradas 1976	"Disconaias" <i>purpurata</i> (Say 1831)
Panuco River system, Mexico	<i>Atacella</i> (A.) sp. nov. Type I
Unionacea	Panuco River system, Mexico
Unionidae	<i>Carunculina parva</i> (Barnes 1823)
<i>Lampsilinae</i> (sensu Davis, et al., 1978)	<i>Atacella</i> (A.) sp. nov. Type III
<i>Popenaias popei</i> (Lea 1857)	Texas, Alabama, and Florida, USA
<i>Atacella</i> (A.) sp. nov. Type I	
Rio Grande system, Mexico and USA	

mussel hosts, our rather intensive sampling of the United States Gulf drainage facilities the assumption that *Atacella* (A.) sp. nov. Type III is specific for *Carunculina*.

This apparent host-parasite specificity suggests that *Atacella* (A.) sp. nov. Type III or its progenitors are not recent immigrants to the northern Gulf drainage area, because *Carunculina* has not been found south of the United States and appears to have no close relatives south of the United States.

At present, however, all speculations about the biogeography and host-parasite co-evolution of *Atacella* and mussels are limited by the current taxonomic discrimination between *Atacella* and *Unionicola*. If the current published concepts of the two genera are accurate, it is safe to assume that the known distribution of *Atacella* is warm-temperate to tropical and that it is not possible to say in which part of the New World *Atacella* originated.

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CEPHALOPODS ATTRACTED TO EXPERIMENTAL NIGHT LIGHTS DURING A SATURATION DIVE AT ST. CROIX, U.S. VIRGIN ISLANDS

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INTRODUCTION

There is worldwide commercial interest in cephalopods, with several fisheries providing significant quantities of octopus and squid for human consumption, animal feed and fishing bait. The great medical scientific interest in cephalopods centers around the squid giant nerve axon. Neurophysiological experiments require the use of live or freshly killed squids; consequently, the availability of these animals for research depends largely upon atraumatic capture and transport techniques. The best methods for capturing live undamaged animals include dipnetting from the surface, fishing artificial lures called squid jigs, and using very large nets (e.g. lampara net or purse seine) to encircle squid schools. To be successful, these methods are usually carried out at night and depend upon the attraction of squids to the immediate vicinity of a night light. The primary aims of this study were to assess the effectiveness of different lights both at the surface and on the bottom by direct underwater observations, and to better understand the attraction of various squid species to a light. The study was conducted during a saturation dive mission from 1-7 September 1978 in NOAA's underwater laboratory system (NULS-1; formerly Hydrolab) in Salt River Submarine Canyon, St. Croix, U.S. Virgin Islands.

It is well known that many cephalopods can be attracted to lights at night but the attraction mechanisms are not understood. Woodhead (1966) and Bearn and Salla (1975) reviewed and summarized most of the current theories of light attraction among marine organisms: 1) positive phototaxis 2) intensity preference (brightness) 3) wavelength preference (color response) 4) conditioned or unconditioned response where light is associated with food 5) curiosity 6) photic disorientation and 7) hypnosis. No one has reliably determined which factors are responsible in any particular species.

Zuev and Nesis (1971) have reviewed many of the light attraction techniques employed in squid fisheries throughout the world. Among these, squids of the genus *Loligo* are important for commercial and scientific purposes. Tardent (1962) reported that *Loligo vulgaris* is attracted to night lights and subsequently captured with lampara nets in the Bay of Naples, Italy. Waller and Wickland (1968) described the attraction of large mating congregations of *Loligo (Doryteuthis) plei* to a lighted underwater submersible at night in the Bahama Islands. Voss (1971 and 1973) has reviewed light attraction of squids in the Caribbean and worldwide. In the U.S., Hochberg and Couch (1971) attracted *Loligo (Doryteuthis) plei* to lights during Tektite II at St. John, U.S. Virgin Islands. Allen and Taber (1974) conducted exploratory squid fishing along the northeast coast of the U.S. They tested different light attraction methods and were consistently able to attract moderate numbers of adult *Loligo pealei*. Bearn and Salla (1975) also attempted to evaluate various light attraction methods for *Loligo pealei* off Rhode Island, but their attempts were seriously hampered by inability to see how squids reacted to the lights and poor weather conditions experienced during their experiments. Kato and Hardwick (1975) have reviewed light attraction techniques for the commercial harvest of *Loligo opalescens* in southern California. In the Gulf of Mexico, we have briefly

reported our results in capturing *Loligo pealei*, *Loligo (Doryteuthis) plei* and *Lolliguncula brevis* (Rathjen, et al., 1979).

Many commercially and scientifically important oceanic squids (Suborder Oegopsida) are also attracted to night lights. Noteworthy among these are *Todarodes pacificus* (Okutani, 1977) and *Dosidicus gigas* (Nesis, 1970; Sato, 1976) in the Pacific Ocean, and *Ommastrephes pteropus* (Baker, 1960; Voss, 1973; Vovk and Nigmatullin, 1972) and *Onychoteuthis banksi* (Voss, 1971 and 1973) in the Atlantic Ocean. In addition to the above mentioned references there are many other anecdotal reports scattered throughout the literature of squid attraction by night lights.

MATERIALS AND METHODS

NULS-1 is a cylindrical four-person underwater habitat, 4.9 m long and 2.4 m in diameter, situated 15 m deep at the base of Salt River Submarine Canyon. The continental margin is narrow and the canyon is in close proximity to deep water. The details of the canyon and the positions of the night light stations are illustrated in Figure 1. The character of the east and west canyon walls is very dissimilar. The West Wall is nearly vertical rock with caves and overhangs. The East Wall is characterized by alternating zones of near vertical rock wall and gently sloping side tributaries of coral rubble. Farther seaward, a more vertical wall predominates on both sides and is populated with a very well developed West Indian coral reef community. The flat canyon floor dips seaward and is composed of medium sand and silt with isolated seagrass beds (mainly *Halophila baillonis*).

Three types of lights were used: non-submersible 500 watt quartz-iodide lights and 250 watt incandescent lights or a submersible 1000 watt mercury vapor light. Figure 2A shows the equipment and general set up for various types of night light stations. The quartz-iodide bulbs were General Electric quartzline lamp, model #Q500T3/CL, with a primary color temperature of 3000°K and brightness of 10,950 lumens. They were equipped with rheostats for dimming. The mercury vapor light was Hydro

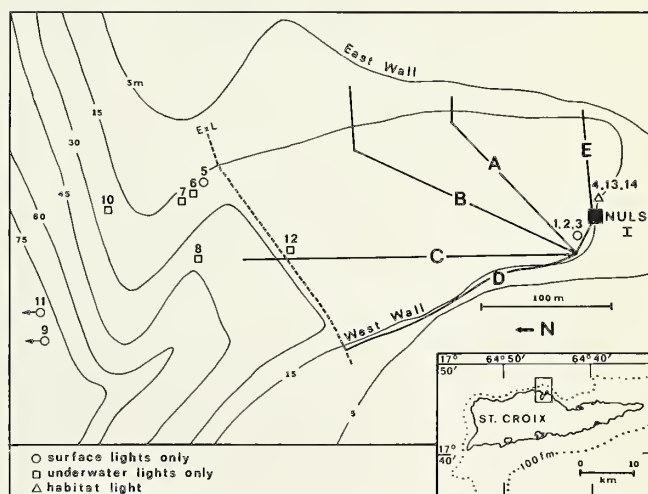


Figure 1. Map of Salt River Submarine Canyon showing its geographic location and the positions of three different types of night light stations. Superscripts indicate station numbers given in Table 1; Stations 9 and 11 were conducted farther offshore. A through E and ExL (standard excursion limit line) are the primary string highways used by divers for bottom orientation.

TABLE 1
CEPHALOPOD NIGHT LIGHTING STATION RESULTS

Sta. #	Date	Time	Depth (m)	Light Type	Light Position		Observations
					U/W	Surface	
1	1 Sept 78	1930-2000	15	Incandescent Quartz-iodide		X	No cephalopods seen. Moderate zooplankton concentration.
2	1 Sept 78	2000-2045	15	Quartz-iodide		X	No cephalopods seen. Moderate zooplankton concentration.
3	1 Sept 78	2100-2140	15	Incandescent		X	No cephalopods seen. Moderate zooplankton concentration.
4	1 Sept 78	2200-2230	13	Quartz-iodide Mercury vapor	X		No cephalopods seen. Quartz-iodide lights operated through habitat viewing port. Moderate zooplankton concentration.
5	2 Sept 78	1940-2045	16	Quartz-iodide		X	Small school of 5 <i>Sepioteuthis sepioidea</i> observed in mid-water by support diver. Heavy zooplankton concentration.
6	2 Sept 78	2045-2155	16	Mercury vapor	X		Observed many individual <i>Abralia veranyi</i> and several individual Macrotritopus. Heavy zooplankton concentration.
7	3 Sept 78	2020-2120	16	Mercury vapor	X		Observed several individual <i>Abralia veranyi</i> and a few individual <i>Sepioteuthis sepioidea</i> , <i>Loligo</i> sp. and <i>Macrotritopus</i> . Collected 3 <i>Abralia veranyi</i> (ML 23-39 mm), 2 <i>Loligo</i> sp. (ML 19 and 20 mm) and 2 <i>Macrotritopus</i> (ML 7 and 9 mm). Heavy zooplankton concentration.
8	4 Sept 78	2100-2130	40	Mercury vapor	X		Observed many schooling and individual <i>Ommastrephes</i> sp. and a few <i>Macrotritopus</i> . Collected 6 <i>Abralia veranyi</i> (ML 20-38 mm). Heavy zooplankton concentration.

9	4 Sept 78	2225-2325	*	Quartz-iodide		X	Observed many schooling and individual <i>Ommastrephes</i> sp. and a few <i>Loligo</i> sp. Collected 14 <i>Ommastrephes</i> sp. (ML 57-86 mm). Station located approximately 1.5 kms offshore. Heavy zooplankton concentration, particularly crab megalopa.
10	5 Sept 78	2200-2330	21	Mercury vapor	X		Observed a few individual <i>Abralia veranyi</i> , <i>Loligo</i> sp., <i>Macrotritopus</i> and <i>Octopus burryi</i> . Collected 1 <i>Loligo</i> sp. (ML 45 mm), 3 <i>Macrotritopus</i> (ML 12-15 mm) and 2 <i>Octopus burryi</i> (ML 13 and 15 mm). Heavy zooplankton concentration.
11	5 Sept 78	2350-0020	*	Quartz-iodide		X	Observed several individual <i>Ommastrephes</i> sp. near the surface and small schools deeper. Collected 3 <i>Ommastrephes</i> sp. (ML 71-80 mm). Station located approximately 1 km offshore. Heavy zooplankton concentration.
12	7 Sept 78	0030-0115	30	Mercury vapor	X		Observed a few individual <i>Abralia veranyi</i> , <i>Ommastrephes</i> sp., <i>Sepioteuthis sepioidea</i> and <i>Macrotritopus</i> . Moderate zooplankton concentration.
13	7 Sept 78	0215-0245	13	Quartz-iodide	X		Observed a few <i>Sepioteuthis sepioidea</i> and 1 <i>Abralia veranyi</i> . Lights operated through viewing port. Moderate zooplankton concentration.
14	7 Sept 78	2000-2130	13	Quartz-iodide	X		Observed several juvenile and adult <i>Sepioteuthis sepioidea</i> . Lights operated through viewing port. Moderate zooplankton concentration.

*Depth unknown but over deep water beyond 100 fm. (183m) line.

Products model L-2, with a non-submersible ballast (transformer) and a 60 m underwater cable. Wavelength equalled 4-6000Å and the brightness was 54,000 lumens. Color slide photographs were taken with either a Nikon F camera and 55 mm Nikkor lens or a Canon F-1 with 50 mm Canon lens and a Rollei E27 electronic flash, all in Ikelite underwater housings.

For surface night light stations a 500 watt quartz-iodide light or a 250 watt incandescent lamp were turned on and observations of attracted squids were made by the surface support technician from the boat or skin diving on the surface. Aquanauts positioned below the surface station also made observations except at stations 9 and 11.

For observations from the habitat, the 500 watt quartz-iodide

lamp was placed at the inside bottom of the large circular viewing port at the east end of the habitat and observations were made from inside the habitat. At station 4 a diver entered the water to check if other cephalopods were outside the view of aquanauts in the habitat.

At underwater night light stations, the 1000 watt mercury vapor light was lowered from the support boat to the aquanauts below. The aquanauts first positioned the light, then during the station recorded observations from behind the directional beam of light. Occasionally one aquanaut would swim out into or beyond the lighted area for further observations. Several live animals were captured in plastic bags for identification.

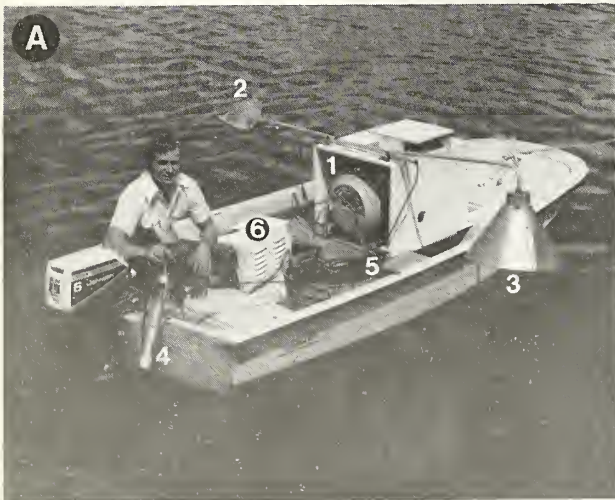


Figure 2A. Small skiff equipped with various night lighting equipment: 1) 1500 watt gasoline-operated generator with wooden cover to protect it from salt spray 2) non-submersible 500 watt quartz-iodide light 3) non-submersible 250 watt incandescent light 4) submersible 1000 watt mercury vapor light with 5) 60 m cable and 6) ballast (transformer).

Figure 2B. *Abralia veranyi* (approximately 40 mm mantle length)

swimming erratically near the reef bottom while mesmerized by the bright mercury vapor night light.

Figure 2C. *Sepioteuthis sepioidea* (approximately 60 mm mantle length) swimming in a version of the "upward V curve" posture while in front of the bright mercury vapor night light.

Figure 2D. Small *Octopus burryi* (approximately 10 mm mantle length) sitting on the bulb of a brightly lighted mercury vapor night light.

RESULTS AND DISCUSSION

We conducted 14 separate night light stations during the study at depths ranging from 13 to 40 m. Total observation time was almost 11 hours with a mean duration of 45 minutes per station (range 30 to 90 minutes). A compilation of the results of each station is given in Table 1. Weather conditions were generally favorable for night lighting throughout the mission and the nights were all very dark during a new moon.

We attracted four squid species to our night lights, including the pelagic squids *Abralia veranyi* and *Ommastrephes* sp., the typically continental shelf form *Loligo* sp. and the reef squid *Sepioteuthis sepioidea*. We observed and collected only small juvenile *Ommastrephes* and *Loligo* and were thus not able to identify them to species. Additionally, we attracted to the underwater light two juveniles of the rarely collected *Octopus burryi* and several of the special octopod "Macrotritopus larvae." Unfortunately, we could not accurately quantify any of our observations due to the erratic swimming patterns of individual cephalopods in and out of the lighted area.

Our first three experiments conducted from the surface near the habitat, as well as our first use of the lamp within the habitat, attracted no cephalopods. We carried out most of our subsequent experiments near the mouth of the canyon in close proximity to deep water where we also encountered clearer water and had better underwater visibility. Underwater stations conducted over reefs in this area (Stations 6, 7, 8 and 10) attracted all six cephalopods collected during this study, while surface night lights (Station 5) did not attract any cephalopods to the surface in the same vicinity. Surface night lights did attract large numbers of juvenile *Ommastrephes* sp. over deep water (Stations 9 and 11) north of the reef margin.

We saw no cephalopods feeding although potential food organisms were also attracted to the night lights. Either moderate or heavy zooplankton swarms were attracted to the immediate vicinity of the lights or to the surface under the above-water lights. We noted small fishes and shrimps at all stations, and crab megalopa were especially numerous at the two offshore stations. From previous observations we have made at other night light stations we know that both *Loligo* and *Ommastrephes* will feed on the size range organisms that was available in the lighted area, indicated that nearly all species were attracted individually and not as a school, and that they did not subsequently group together during the station. Some small schools of five to 20 *Ommastrephes* sp. were observed at Stations 9 and 11 and a school of five *Sepioteuthis sepioidea* was seen at Station 5, but mostly single individuals of both species were seen during the study. Published descriptions and our own previous observations have shown that *Ommastrephes*, *Loligo* and *Sepioteuthis* are usually schooling animals, especially juveniles. The *Macrotritopus* attracted to the underwater lights also occurred only as individuals.

All species appeared disoriented while in the immediate vicinity of the lights. *Abralia veranyi*, *Sepioteuthis sepioidea* and *Ommastrephes* sp. assumed a type of distinctive "upward V curl" posture (Moynihan, 1975) in which all or most of the arms on both sides of the body were held upward and somewhat backward forming a V (Figure 2C). This posture and its associated color arrangements are thought to be an indication of alarm, possibly allowing the squid to thwart predators by mimicking or hiding in drifting *Sargassum* weed or gorgonians. The *Ommastrephes* sp. attracted over deep water were so agitated that several jetted out of the water, with four of them landing in our night light

boat. *Ommastrephes* propel themselves out of the water to avoid predators and are commonly known as the flying squid. At no time during the stations did we observe any predators (except perhaps ourselves) that could elicit such responses.

The very bright underwater lamp (54,000 lumens) appeared to daze or mesmerize the cephalopods. *Loligo* sp., *Abralia veranyi*, *Octopus burryi* and *Macrotritopus* were drawn to the light and occasionally swam very near to it through the accumulated zooplankton swarm. In fact, the two *Octopus burryi* were collected as they crawled onto the light bulb itself (Figure 2D). It is very possible that the absence of normal schooling or feeding behavior and the defensive posture and escape reactions we observed were due in part to the intensity of our night lights.

Overall, few cephalopods were attracted to our night lights. We conclude that the small area in which we conducted our stations supported few pelagic cephalopods, particularly the shelf form *Loligo*.

Since we attracted few animals, it was not possible to properly compare the effectiveness of our night lighting techniques or clearly establish which factors influenced attraction. Many other workers (Maeda, 1951; Woodhead, 1966; Polutov, 1970; Zuev and Nesis, 1971; Vovk and Nigmatullin, 1972; Bearnse and Sails, 1975; Allen and Taber, 1974) have also noted the highly varying results of light attraction of squids and the poor understanding of attraction mechanisms. The results among workers are often so contradictory and inconsistent that presently it is difficult to make sound evaluations of different lighting schemes. It is likely that there is a species-specific response to light and, in addition, that a host of other factors such as hydrographic conditions, moon phase, food availability and sexual condition can influence individual squid behavior in relation to artificial light.

We feel that the method of placing saturation divers underwater with simultaneous surface observations could help establish which factors effect the attraction of squids to light. In the future, very specific experiments that would test individual factors in light attraction should be designed. In addition, special attention must be made to accurately quantify observations made at night.

ACKNOWLEDGEMENTS

We thank the support personnel of NULS-1 for their professional and competent assistance during the dive mission. Deirdre A. McConathy drew Figure 1. We also thank Drs. Michael A. Heeb and J. Morgan Wells for encouraging us to undertake this project. Use of the habitat was obtained through NOAA's Manned Undersea and Technology (MUST) Program. Financial support was obtained from Sea Grant No. OMB 41-R2779 and the Marine Medicine General Budget account #7-11500-765111 of the Marine Biomedical Institute, University of Texas Medical Branch, Galveston, Texas.

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A UNIQUE METHOD OF AGING SURF CLAMS

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INTRODUCTION

Within the range of the Atlantic surf clam, *Spisula solidissima* (Dillwyn), from Cape Hatteras, North Carolina, to the Gulf of St. Lawrence, Canada, most of the shells collected for aging by the National Marine Fisheries Service are from the extensive Middle Atlantic continental shelf and areas containing fishery concentrations (Ropes 1979; Serchuk et al 1979). An objective of the collections is to assess population age composition. Such analyses require that accurate ages be determined for all clams in a sample and for the two to three thousand clams taken during a research survey cruise. Thus, rapid, simple processing techniques are needed that result in study specimens showing growth marks in as clear definition as possible.

Problems in the interpretation of all growth marks in some shells were encountered during studies begun in 1975. For large clams, erosion of the external valve surfaces deposited in the earliest years of life and crowding of growth marks during later years made precise age determinations difficult or impossible; some valves exhibited very irregular marks, complicated by an overlapping of shell. Sawing through shells from the umbo to ventral margin, followed by grinding and polishing the cut surfaces, improved detection of growth mark deposition (Chang et al 1976). Later, Jones et al (1978) reported on a study of aging surf clams using the same technique.

The speed of cutting shells was increased by modifying a diamond blade saw machine, but polishing the cut edges to enhance growth mark detection was a laborious, time consuming process. Microscopic examination of the cut shell was tedious,

requiring two independent observations per shell for an assurance of accuracy. Even with this precaution, differences in counting growth marks were not easily resolved. Accurate measurements of growth increments also posed technical difficulties.

Chang et al (1976) found correspondence between the number of growth marks in the chondrophore and valve of surf clams and related chondrophore length to shell length and cross-section dimensions. Consequently, techniques were developed to produce thin-sections of the chondrophore. It is a small, easily processed part of the valve. As part of the hinge, it and the umbo are often all that remains of broken clams in a sample. After describing the methodology, examples of thin-sectioned chondrophores are given and an analysis relating measurements of increments at growth marks in the chondrophores and valves of a sample.

METHODS

Preliminary to thin-sectioning, a piece of the chondrophore was excised from the valve hinge. Right-hand valves were routinely chosen, since this simplified positioning successive valves for cutting. A valve was clamped on a hinged table over two 25-cm-diameter by 0.096-cm-thick diamond saw blades separated on the saw arbor by a 0.635-cm-wide flange.¹ The cut of the blade nearest the anterior end of the valve was critical. To insure including the umbo in the excised piece, the blade nearest the anterior end of the valve was oriented to pass through the chondrophore immediately anterior to the umbo and directed to a point at the ventral margin of the valve which, if completed, would separate the posterior quarter from the remainder of the valve (Fig. 1). This is the same plane of section used by Chang et al (1976) and Jones et al (1978). In this new method, however, parallel cuts were made only through the chondrophore just beyond the umbo area. Gravity forced the valve into the fast-

turning blades (1725 rpm) and the cuts were made in less than a minute. After removing the valve from the saw table, the chondrophore piece was broken away with finger pressure. Medium to fine (220, 400, and 600 grit) wetable carborundum paper was used to grind and polish the anterior cut surface of the piece down to the umbo, producing a flat surface free of saw marks, and the excess valve material was trimmed off. The piece was air dried and mounted on a glass slide by applying a two-part epoxy glue to the polished surface.² These steps were usually accomplished in about two minutes per piece. After the glue hardened, the slide was mounted on a vacuum chuck of a low speed (0-300 rpm) saw with the flat surface parallel to a precision 10.2-cm-diameter by 0.03-cm-thick diamond wafering blade.³ Adjustment for distances away from the glass slide and thickness of the sectioned chondrophore was by a micrometer assembly on the saw unit. Thin-sections of the largest chondrophores were produced in about 15 minutes.

Slide preparations were suitable for viewing under a microscope and as a transparency mount in a slide projector. Photographic enlargements have been made using the actual thin-sectioned preparations as a negative. The latter has potential value for archiving age information.

Thin-sections (ca. 0.023 cm) of chondrophores from three offshore locations were prepared for examination: a 27 m deep bed at 36°33'N., 75°21' W. off False Cape, Virginia, on December 16, 1975; a 7.3 m deep bed at 38°04' N, 75°05' W. off Chincoteague, Virginia, on December 12, 1975; and a 22.9 m deep bed at 39°17' N., 74°23' W. off Ocean City, Maryland, on March 23, 1978. A Stimpson's surf clam, *Spisula polynyma* (Stimpson), taken in Bering Sea samples and sent to me by Stephen E. Hughes of the National Marine Fisheries Service Northwest and Alaska Fisheries Center, was prepared for comparison with Atlantic surf clam preparations.

RESULTS

Well delimited growth occurred in eleven False Cape, Virginia, surf clams ranging from 140 to 166 mm in shell length. The number and spacing of growth bands in the chondrophore of the 140 mm long clam was typical of the others in the sample (Figure

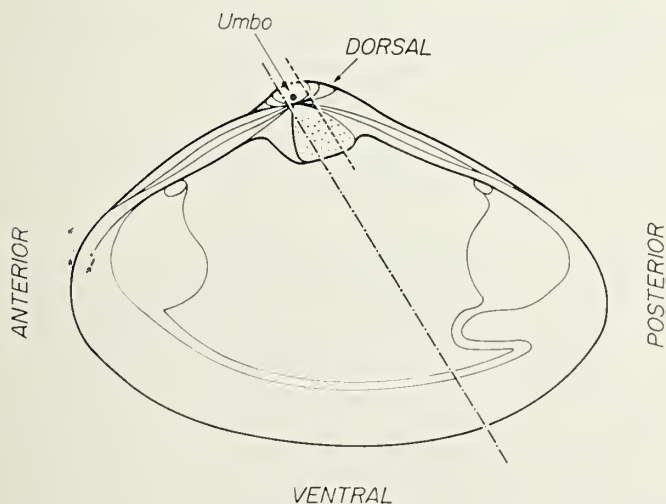


Figure 1. Plane of section to excise part of the chondrophore (lightly stippled area) from the valve of a surf clam, *Spisula solidissima*.

2a). In the photographic print, dark, narrow growth bands were separated by broad white areas, but under the microscope, light transmitted through the chondrophore revealed a faint translucent growth band very near the umbo followed by eight distinct narrow bands. Broad opaque areas were intergraded between the bands. The terminal band had not completely formed, since the distal margin of the chondrophore lacked opaque shell deposition. As is discussed, the number of bands found in these examinations may not indicate that the clams were nine years old.

Slightly different growth was seen in ten Chincoteague, Virginia, clams ranging 137 to 165 mm in shell length. The number and spacing of growth bands in the chondrophores of clams 137 and 148 mm were typical of others in the sample (Fig. 2b & c). A faint band was followed by thirteen more distinct bands and although opaque areas clearly separated the bands, they diminished in size nearest the distal margin. The formation of the terminal band in some clams, however, was unlike that seen for the False Cape, Virginia, clams. Six, including the 136 mm clam (Fig. 2b), lacked opaque shell deposition at the distal margin and four, including the 148 mm clam (Figure 2c), had a rim of opaque shell. Terminal growth band formation had apparently been completed for the latter, but not the former clams.

The separation between bands near the distal margin of the chondrophore in a 177 mm clam from off Ocean City, Maryland, was much less pronounced than was seen for smaller clams (Fig. 2d). Opaque areas clearly demarcated the earliest fifteen bands, but thereafter band deposition appeared equal to or was greater than opaque shell deposition. A maximum count of 30 bands was made for this specimen.

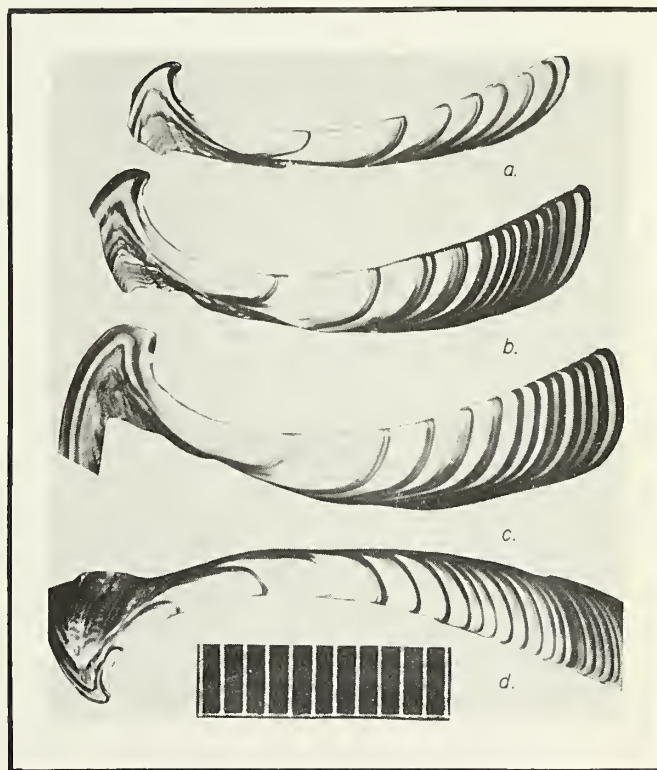


Figure 2. Photographic enlargements of thin-sections of the chondrophores from surf clams (a) 140, (b) 137, (c) 148, and (d) 177 mm in shell length. A millimeter scale is included.

Measurements indicated a linear correspondence between chondrophore growth and valve growth. Distances from the umbo to each band on the chondrophore were regressed upon the valve length for the corresponding external band, using least squares technique. The plotted values and fitted regression line are shown in Fig. 3. The relatively high correlation coefficient ($r = 0.97$) indicated a synonymy of growth within the two structures since 94% of the variation between chondrophore and shell length was accounted for by the regression equation.

Growth bands in the chondrophore of other pelecypod species may be more clearly seen in thin-sectioned preparations. A 134 mm Stimpson's surf clam (*S. polynyma*) had bold ridges, suggestive of growth marks, on the eroded external shell surface. In a thin-sectioned shell preparation, bands terminated at many of the ridges, but for a few there was no definite external ridge. The bands in the thin-sectioned chondrophore were equally as distinct as in the valve (Fig. 4). A maximum count of 30 bands was made for this specimen.

DISCUSSION

Shell deposition indicative of age marks in the chondrophores and valves of surf clams have been called "growth marks" or "growth bands" rather than "annuli" in this paper; Jones et al (1978) used the term "internal growth lines" for such deposits, because the time and cause of formation of the deposits are incompletely known. Jones et al (1978) found the earliest growth line in young notched clams 60 to 74 mm sampled in the shallow water off Chincoteague, Virginia, coincided with the time of notching on December 12, 1964; a second line appeared when the shells averaged 44 mm in length during an estimated late July to late August 1965 period. In the present study, clams sampled from offshore Virginia in mid-December 1975 exhibited terminal bands that were complete or nearing completion. The appearance of growth bands in the mid-December samples of both large

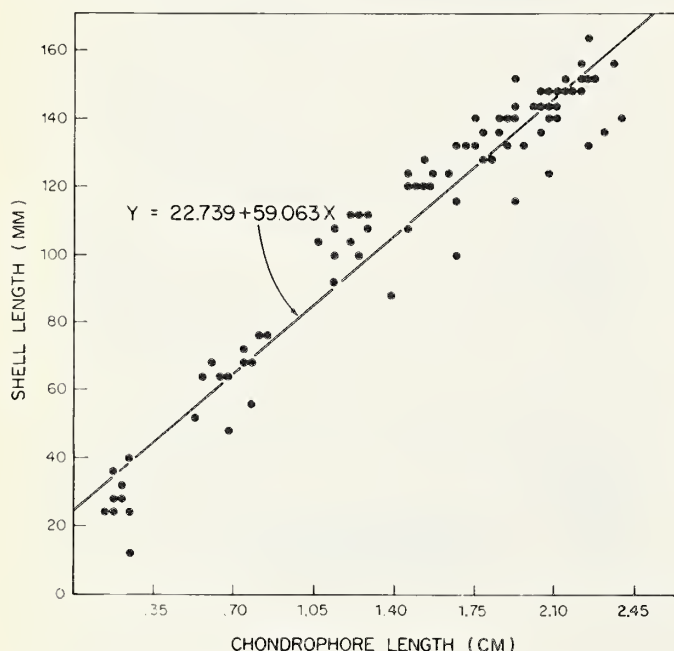


Figure 3. Plotted length measurements at corresponding growth bands in the chondrophores and valves of surf clams from False Cape, Virginia.

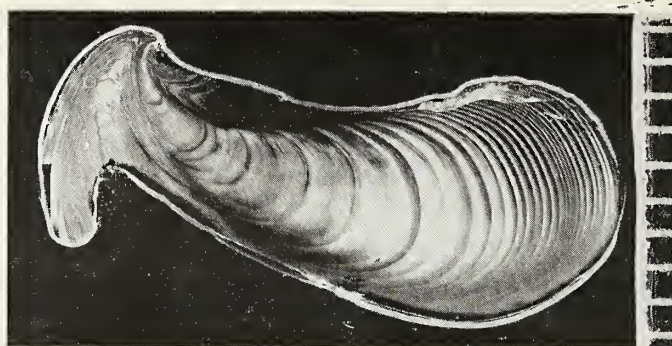


Figure 4. Photographic enlargement of the thin-sectioned chondrophore of a Stimpson's surf clam (*S. polynyma*) 134 mm in shell length. A millimeter scale is included.

offshore and small inshore clams, the complete development of such deposits in the shells of some individuals, and well-developed but incomplete deposits in others, suggests formation had been in progress during the latter fall period when decreases in water temperature are expected. A relationship between the formation of growth bands and temperature, however, has not been established.

The relative ease with which bands in thin-sectioned chondrophores of surf clams can be viewed by the three means of enlargement compensated for the time spent in preparation. The steps in preparing a slide are fairly straightforward. A student with no previous experience in aging or the sectioning equipment worked almost half-time on this project for a month. He produced prints of 56 chondrophores while learning the techniques. The equipment and materials are available and modifications of one saw are minor. It is conceivable that increased microstructural detail can be viewed without impregnating and mounting in epoxy resins, as was recommended for fossil and recent organisms by Nye et al (1972). It was necessary to support sections of the valve with a fast hardening epoxy auto body filler during grinding operations. The thin-sections may also be useful in experimental staining of shell deposits, viewing under a scanning electron microscope, or producing acetate peels of the polished and etched surface for detailed examinations.

ACKNOWLEDGEMENTS

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¹A Raytech 10" Slab and Trim Lapidary Saw and two Red Blazer blades manufactured by Raytech Industries, Inc., Stafford Springs, Conn. were used. References to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

²Elmer's Epoxy Cement, Borden, Inc., Columbus, Ohio.

³An Isomet Low Speed Diamond Saw and high concentration watering blade manufactured by Buehler, Ltd., Evanston, Ill. was used.

ABSTRACTS OF PAPERS PRESENTED AT THE 1979 MEETING

A COMPARISON OF INTERTIDAL DISTRIBUTION, GROWTH RATES, AND SHELL POLYCHROMISM BETWEEN TWO FLORIDA POPULATIONS OF THE COQUINA CLAM, *DONAX VARIABILIS* SAY, 1822 (BIVALVIA: DONACIDAE)
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ABSTRACT

Monthly collections of *Donax variabilis* from two locations on the central eastern (Indialantic Beach) and southwestern (Sanibel Island) coasts of peninsular Florida revealed a population of *D. variabilis* at Sanibel sixty times greater, per linear meter of beach, than that of Indialantic. This was probably due to lower beach slope and wave energy at Sanibel. Intertidal migrations occurred constantly at Indialantic, with the *Donax* maintaining a position about the center of the swash zone. Sanibel *Donax* were nonmigratory and lived predominantly at low intertidal levels.

Average summer growth rates were 3.0 mm and 3.7 mm per month for Sanibel and Indialantic *Donax*, respectively. Spawning occurred on the east coast around late February and mid-June. On the west Florida coast, *Donax* also spawned in late February, but the second spawning was in mid-May.

Munsell color charts were used to designate 174 color forms, 85 (49%) of which occurred at Sanibel, 188 (68%) at Indialantic, while only 29 (17%) were common to both populations. The unrayed forms dominated both populations, with 93% of the Indialantic population unrayed and 82% unrayed at Sanibel. Environmental parameters of organic leptonel concentration, temperature and salinity did not influence shell coloration. The general ground coloration of the shells did not significantly differ between populations.

NOTES ON THE ECOLOGY OF EAST AMERICAN DONAX

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ABSTRACT

All *Donax* species listed from Eastern America show ecological separation. In four cases, *Donax fossor*, *D. roemeri*, *D. parvula*, *D. dorotheae*, and *D. texasiana* have been found living in pairs on the same shorelines, yet maintain their specific identity.

SPONDYLUS PRINCEPS BRODERIP IN ECUADORIAN ANTIQUITY

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ABSTRACT

Since *Spondylus princeps* Broderip 1833, known to the coastal Ecuadorian Indians as "mullu," was an item of great personal and trade value, I hoped to determine to what extent La Plata Island had been involved throughout the various time periods.

So far, artifacts dating to the early Chorrera (1100 B.C. to 100 B.C.) have been discovered on La Plata. Worked and unworked *Spondylus princeps* have been found from all levels so far uncovered.

Living *Spondylus princeps* have been found between 68 and 135 feet deep but not in sufficient numbers to have made this a primary site for the millions of specimens that the Indians were utilizing.

The question arises as to how the Indians obtained the specimens that they did use. Diving to the depths at which *Spondylus princeps* is found and then having enough bottom time to locate them, and to ascend would be almost physically impossible. Since both stone and coral weights have been found in the excavations, and since wild cotton grows on the island, it is my belief that nets were made from the cotton, weighted down, and then used as trawls to gather *Spondylus*.

THE KARYOTYPE OF *ISOGNOMON ALATUS*, GMELIN, 1791 (PTERIODA-ISOGNOMIDAE)

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ABSTRACT

In the genus *Isognomon* the only known chromosomal study was done by Wada in 1978. Many important karyological aspects for the cytotaxonomy of this taxon such as the diploid numbers, the chromosomal morphology and the meiotic behaviour, are still unknown. These are events that help to establish the degree of karyotypic stability both at an intraspecific and an interspecific level in populations from different geographical locations.

Our results show *Isognomon alatus* to have a diploid number (2n) of 28; the chromosomes are classified as metacentrics (pairs 1, 3, 4, 6); submetacentrics 2, 5, 7, 8, 9, 12 and 13; subtelocentrics pair 10 and acrocentrics pairs 11 and 14. No sexual chromosomes were identified. Fourteen bivalent meiotic complexes (n) were observed at diakinesis.

MODES AND DEGREES OF ADAPTATION TO DESICCATING ENVIRONMENTS IN THE GENUS *CREPIDULA* (PROSOBRANCHIA: CALYPTRAEIDAE)

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ABSTRACT

When exposed to air *Crepidula convexa* remains attached to the substrate, while *C. fornicata* gapes widely. Experimental desiccation of specimens of *C. convexa* and *C. fornicata* showed that *C. fornicata* were less tolerant of desiccation than *C. convexa* of the same size, because *C. convexa* could retain water under its shell. In nature, *C. convexa* is more frequently exposed to air than is *C. fornicata*. Different modes and degrees of adaptation to desiccating environments reported for species of marine mussels parallel those seen in *Crepidula*.

HOW MANY SPECIES OF *ACANTHOTROPHON* ARE THERE, ANYWAY??

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ABSTRACT

Although it has been suggested that they may all be the same species, it is my opinion that *Acanthotrophon* comprises a total of five species: *A. carduus*, *A. sorenseni*, and *A. sentus* from the eastern Pacific; and in the western Atlantic, *A. striatus*, a Miocene form, plus an unnamed Pliocene to Recent species heretofore included with *A. striatus*.

ESTIMATING THE SIZE OF SMALL GASTROPODS FOR COMPARATIVE PURPOSES

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ABSTRACT

An outline of the shell is projected on to quadrille paper by camera lucida. The projection should include more than 100 quadrille units. Dimensions of the quadrille units at that magnification are obtained with an objective micrometer. Units and more than 1/2 units are counted and converted to square millimeters.

THE SYSTEMATIC STATUS OF PROSERPINOID LAND SNAILS

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ABSTRACT

Proserpinoids have conventionally been classified in one group, either as a distinct family, Proserpinidae, or as a subfamily of the Helicinidae. The union of proserpinoids as a single group was based on the non-operculate, lamellate shell characteristic of the different genera. Studies of the soft anatomy indicate that proserpinoids comprise two separate families: 1) the Ceresidae, which is dioctocardial and primitive in character compared to all other Helicinacea and Neritimorpha; and 2) the Proserpinidae which has a relationship with primitive Helicinidae (Henderstoniinae). The Proserpinidae is endemic to the Greater Antilles. The Ceresidae is distributed in Mexico and South America.

RELATIONSHIPS BETWEEN ENVIRONMENT AND SHELL SHAPE IN *PARTULA OTAHEITANA*: A REASSESSMENT OF CRAMPTON'S 1916 DATA

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ABSTRACT

Multivariate statistical analysis of Crampton's data from Tahiti nui suggests that populations of *Partula otaheitanus* in wetter, more shaded valleys tend to have shells more elongate, darker in color, with a higher percentage of banding, and with lesser development of a parietal tooth than populations from dryer, more sunlit valleys.

"SHE BE RIGHT, MATE" — CLASSIC AUSTRALIAN AWARENESS

Alan Solem

Field Museum of Natural History
Chicago, IL

ABSTRACT

Patterns of species recognition devices and habitat specializations in camaenid land snails from the semi-arid regions of the Kimberly District, northwestern Australia provide insights into how closely related species living together can partition niches and avoid interspecific mating.

SEASONAL MOVEMENT PATTERNS IN *TRIODOPSIS ALBOLABRIS MAJOR* (PULMONATA: POLYGYRIDAE)

Virginia A. Vail

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ABSTRACT

Nearly 600 *T. albolabris major* have been marked in Thomasville, Georgia. A general trend in seasonal activity patterns was observed. In the colder months the snails are found in protected areas. During the rest of the year they are in the litter and vegetation.

There was a great amount of movement within the winter dens as well as into and out of them. Individuals tended to return to the same or a closely adjacent den site each winter. Recaptures during the rest of the year strongly suggest the presence of an individual "home range."

To study the home range further as a means of following individuals had to be devised. Experimentation lead to the use of radio telemetry to monitor snails' movements. Proto-types of such miniature transmitters have been developed and successfully field tested.

SYSTEMATICS AND EVOLUTION OF GALAPAGOS

GASTROCOPTA

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ABSTRACT

Eight taxa have been identified from the Galapagos; 4 are new to science, 1 is newly recorded from the archipelago; 7 form a closely related taxonomically difficult, endemic group, 1 is indistinguishable from a mainland species. The roles played by speciation, character displacement and hybridization are discussed.

HAWAIIAN CHROMODORIDS

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ABSTRACT

Taxonomy and ecology of subtidal populations were discussed.

MANTLE GLANDS OF THE LYONSIIDAE (BIVALVIA)

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ABSTRACT

Lyonsiidae are usually cryptic in habitat. *Lyonsia*, a shallow burrower, attaches sand grains to its shell. *Entodesma* is found tucked within rocky crevices and may attach foreign particles to its shell, and *Mytilimeria* settles on and is eventually embedded within compound tunicates. Mantle glands of *Lyonsia* and *Entodesma* produce a mucoprotein which acts as the adhesive for the attachment of the extraneous material to the shells. Mantle glands are numerous in most *Lyonsia* and juvenile *Entodesma* but may be gradually lost with growth in the latter. No glands have been found in adult *Mytilimeria*.

Based on shell form and ultrastructure and the muscular, byssal and mantle systems, it is likely that the lyonsiid lineage stems from a single *Lyonsia*-like ancestor from which arose separate lyonsiid and entodesmid branches. This ancestral bivalve may have had a "typical" mantle edge which possessed mucocytes proximal and distal to the periostracal groove. These mucocytes may have been the anlage for parallel development of the morphologically similar but distinctly located mantle glands of *Lyonsia* and *Entodesma*. *Mytilimeria* descended from the entodesmids through loss of the mantle glands and a regression of muscular and pedal systems.

THE ULTRAMORPHOLOGY OF THE SHELL OF *CORBICULA LEANA PRIME* (BIVALVIA: SPHAERIACEA: CORBICULIDAE)

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ABSTRACT

Scanning Electron Scope examination of fracture sections reveals an entirely complex cross-lamellar shell. Shells treated with 2% sodium hypochlorite demonstrated a cyclic series of concentric microridges with varying surface sculptures. Outer shell surfaces were generally perforated with small pits, some of which were aligned to form radial grooves. This pattern changed to a thicker, radially arranged cord-like zone which ended abruptly at points which seemed to mark a change in shell growth. New shell appeared to be laid down from beneath the transition bands and alternated between areas of perforated ungrooved shell and shell surfaces which were smooth and lacked perforations. The latter zone was terminated by a narrow concentric ridge which was followed by the deeply perforated, rugose shell surface initially described.

The pattern of banding seen in the shell may represent periods of energy redirection during gametogenesis. SEM examination of a periostracal loop emerging from the periostracal groove and then recurving over the shell demonstrated that the inner surface, which adjoins the shell, is also rugose. This ultramorphology of shell and periostracum may explain the high degree of bonding between these structures in *Corbicula*.

THE NAIAD FAUNA OF THE POWELL RIVER IN VIRGINIA AND TENNESSEE

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ABSTRACT

Thirty-six species of freshwater mussels (Unionidae) were found living in the Powell River. Fourteen of these are "Cumberlandian" species which are endemic to the southern Appalachian Mountains and the Cumberland Plateau.

GENETIC DIFFERENTIATION AMONG SOME NORTH AMERICAN UNIONIDAE

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ABSTRACT

The results of a multivariate analysis of the genetic relationships among 52 species of Unionidae involving a data matrix of 52 species X 21 sets of antisera were discussed. The data elements were the % difference among taxa involving 10 to 12 proteins. The % difference was calculated following immuno-electrophoresis with absorbed antiserum. Allozyme analysis of 26 populations involving 17 loci and 105 alleles confirms the immunological results; i.e. the separate clusters of Margaritiferinae, Anodontinae, Lampsilinae; the separation of Lampsilini and Elliptionini; the close association of *Fusconaia* and *Elliptio*.

MUSSELS (NAIADES) OF THE MERAMEC RIVER BASIN, MISSOURI

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ABSTRACT

Forty-five species of naiades were found during a survey of the Meramec River Basin, Missouri. Two species, *Simpsonia ambigua* and *Anodontoides ferrussacianus*, had not previously been reported from Missouri. The lower 100 miles of the Meramec provides valuable habitat for *Lampsilis o. orbiculata*, *Cumberlandia monodonta* and *Leptodea leptodon*.

THE USE OF A SMALL COMPUTER FOR DATA HANDLING AT THE LACM-NH

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ABSTRACT

In April, 1979, the Malacology Section of the Los Angeles County Museum of Natural History acquired a small computer for data handling and specimen label printing. Our experience with it and the relative merits of small in-house vs. remote time-share systems, interactive vs. batch processing and custom vs. generalized data handling programs was discussed.

NEW RECORDS OF MOLLUSKS AT FERNANDO DE NORONHA ISLAND, BRASIL

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ABSTRACT

Associate researchers of Rio Grande Oceanographic Museum (Brasil) went to Fernando de Noronha Is. in January, 1979. They stayed there 25 days and collected mollusks in tide pools, under intertidal rocks, by diving and dredging at 15 meters. In this paper, we present the principal shells collected and the new records.

DISTRIBUTION OF SOME SMALL MOLLUSCS IN THE NORTHEASTERN GULF OF MEXICO

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ABSTRACT

Micro-molluscs are distributed over the continental shelf according to depth — temperature and substrate requirements. The fauna changes out near the edge of the shelf. The most noticeable change occurs where the clastic sediment load is heavy.

FILTER FEEDING ASIDOBANCH LIMPETS FROM SUBMARINE THERMAL SPRINGS OF THE GALAPAGOS RIFT

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ABSTRACT

The "nift limpet" is convergent in form and function with the Calyptraeidae. Its radula is rhipidoglossate and the gill is the first reported

bipectinate gastropod ctenidium modified for filter feeding. Several lines of evidence suggest that the nift limpet is a descendent of an archaeogastropod suborder that was prolific during the Paleozoic.

THE ZOOGEOGRAPHY OF TALL SNAILS IN THE CENTRAL AND WESTERN PACIFIC

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ABSTRACT

The occurrence of tall land snail shells (in Cain's upper scatter) derived from very different stocks in different countries in and around the Central and Western Pacific has long been recognized taxonomically. When shell height (h) and maximum breadth (d) are plotted for each species for each fauna it is found (a) that the upper scatter is tripartite with the submodes U_1 , U_2 and U_3 very differently represented in different faunas, (b) that there is an ecologically surprising paucity of tall snails in the Papuan region, and an apparent excess on Kauai, and (c) that in Hawaii, the Philippines and New Guinea tall fat shells (U_3) are produced by continuous extension of shell shape from the lower scatter; elsewhere tall shells and equi-dimensional-to-discoidal ones are not connected. While the affinities of some tall snails in this region point to old Gondwanaland distributions, it is suggested that their present deployment in relation to h and d may be very recent.

SHALLOW WATER MOLLUSCAN ASSEMBLAGES IN PUNTA MORÓN, GOLFO TRISTE, VENEZUELA

Pablo Penchaszadeh, R. Colmenares and M. Layrisse

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Caracas, Venezuela

ABSTRACT

Several communities with characteristic molluscan fauna were found from 0-10 m deep near a thermoelectric facility. A map of species distribution was presented.

THE GENUS ACANTHINA FISCHER, 1807 IN THE AMERICAS

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ABSTRACT

The genus *Acanthina* is a small group of muricid gastropods, having a distinct spine on the outer lip of the aperture and distributed geographically in Americas from California south to Cape Horn and neighboring islands. Shells, opercula, radulae, digestive and reproductive systems and geographical distributions of 9 species were studied. Preliminary results indicate that (1) there are all sorts of intermediate shell forms between the species *A. angelica* and *A. lugubris*, and also between the species *A. crassilabra* and *A. calcar*, and (2) based on shell, radular and anatomical characters, *A. brevidentata* and *A. tuberculata* differ from other members of *Acanthina*. *Acanthina brevidentata* should be relegated to the genus *Thais*, and *A. tuberculata* to the genus *Mancinella*.

ASPECTS OF THE ANATOMY OF RHODOPETALLA ROSEA (DALL) (ACMAEIDAE)

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ABSTRACT

Anatomical studies of a large series of live collected animals (Amchitka Island, Aleutian Islands, Alaska) reveal that *R. rosea* is an acmaeid limpet. However, several aspects of its anatomy differ from previously studied species. The gill is vestigial and lacks a solid ctenidial axis, ctenidial filament, and distinct ciliary bands. Instead its structure closely resembles that of the individual lappets that make up the branchial cordon of the patellid limpets. Only a small portion of the blood enters the gill. Most of it circulates through a haemocoelic space in the roof of the nuchal cavity. At the posterior of the nuchal cavity blood from the roof spaces mixes with blood from the gill before entering the auricle of the heart. The auricle has only an efferent vessel, the circummantle vessel is absent and the heart of *R. rosea* shows aspects of both patellid and acmaeid hearts. Respiration appears to be carried out on the surface of the roof of the nuchal cavity; this is similar to the patellid limpets. The nuchal cavity of *R. rosea* is larger

than in most acmaeids and the nephridia extend into it along the roof. Almost the entire left nephridium is contained within the nuchal cavity while a corresponding portion of the right nephridium is also included therein. The nephridiopores open ventrally rather than distally as in other acmaeids.

THE CHROMOSOMIC PERICENTRIC INVERSIONS AS AN ADAPTIVE MECHANISM IN THE KARYOTYPE OF THREE SPECIES OF *CRASSOSTREA*

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ABSTRACT

The chromosome features of the karyotype of the genus *Crassostrea* are believed to be similar in gross morphology and diploid number. Chromosome studies in the oyster species *Crassostrea virginica*, *C. rhizophorae* and *C. corteziensis* from the Mexican coast were made to compare the chromosome features of their karyotypes by means of the measure and classification of chromosomes. It was concluded that *C. rhizophorae* and *C. corteziensis* differ only in the position of the centromere in one chromosomal pair. This could be explained by the pericentric inversions.

CORRELATION OF LAND SNAIL DISTRIBUTIONS WITH GEOLOGICAL SUBSTRATE IN CENTRAL TEXAS

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ABSTRACT

Travis County, Texas, is traversed by the Balcones Fault Zone, a major ecotonal area which limits the distribution of numerous plant and animals including a number of terrestrial gastropods.

Primary factors limiting snail distribution in this area may include rock substrate, chemistry of derived soils and resultant vegetational communities which provide both food and shelter.

MICROANATOMICAL STUDIES OF THE KIDNEY OF THE SLUG, *DEROCERAS LAEVE*

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ABSTRACT

The kidney of *Deroceras laeve* is essentially a tube with numerous folds of epithelium projecting into its central area. The epithelial layers of a fold are separated by a zone of connective tissue and blood spaces the thickness of which seldom exceeds the height of the cuboidal to columnar epithelial cells. In most cross sections the area occupied by the kidney cavity exceeds that occupied by the epithelial folds. The short (about 0.1 mm), inconspicuous renopericardial canal is located at the ventricular end of the pericardial cavity. The kidney cavity opens broadly to a primary ureter which ends at a chamber with a flap-like valve, closure of which would prevent flow of fluid on to the secondary ureter (bladder) portion of the duct system. The secondary ureter is lined by a low cuboidal epithelium. At irregular intervals depressions in this epithelium are occupied by large cells, each of which bears a conspicuous tuft of closely spaced cilia.

AN ASPECT OF THE POPULATION GENETICS OF THE AMERICAN OYSTER, *CRASSOSTREA VIRGINICA*¹

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ABSTRACT

Four races of the American oyster (*Crassostrea virginica*) from two geographical areas, the Navesink River, New Jersey and the New Haven Harbor, Connecticut were genetically screened utilizing starch gel electrophoresis. The four races represented two pairs of third generation inbred populations and the wild populations from which they were derived. Each generation was subjected to selective pressure caused by

the disease organism *Minchinia nelsoni* (Haplosporida, Haplosporidiidae).

Five polymorphic enzyme systems were chosen for full screening. These included phosphoglucose isomerase (PGI), glutamate oxaloacetate transaminase-2 (GOT-2), leucine amino peptidase-1 and -2 (LAP-1, LAP-2), and malic dehydrogenase-2 (MDH-2). Sample sizes varied from 48 genes for the inbred Navesink River population to 116 - 124 genes for the remaining three populations. Allelic frequencies were determined for all gene loci examined.

The genetic effects of inbreeding were observed in the reduction of average heterozygosity, as demonstrated by a decrease in the number of alleles per locus in all but one loci examined. Rare alleles were most readily lost from the gene pool. Over four gene loci (MDH-2 was monomorphic), the Navesink River populations displayed an average reduction in the number of alleles per locus from 4.5 in the wild stock to 2.0 in the inbred stock, a decrease of 55.6%. Over five loci, the New Haven material exhibited an average reduction from 3.2 to 2.0 alleles per locus, a drop of 37.5%. Trends toward fixation of a single allele in the inbred strains were observed. In two cases fixation did occur.

Reduction in genetic variability was shown to be a potential consequence of inbreeding. Reduced variability in the form of lowered heterozygosity may have deleterious effects on the overall fitness of a population by lowering evolutionary capabilities. Evidence suggests that safeguards need to be incorporated into breeding projects, including mariculture, which involve inbreeding for the purpose of optimizing a desired characteristic. In those organisms engaging in mass spawning, the utilization of large numbers of individuals in each spawning group would aid in reducing the level of inbreeding. Crosses with populations from other geographical areas would also aid in maintaining desired levels of heterozygosity.

¹This study was conducted at the Department of Zoology, Rutgers University, under the direction of Drs. Harold H. Haskin and Robert C. Vrijenhoek, to whom the author expresses great appreciation.

TEXAS NIGHT

ORAL HISTORY OF MALACOLOGY

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ABSTRACT

Money was obtained from the Faculty Research and Development funds of Trinity University to initiate an oral history of malacology. What started as a single effort to record the life and experiences of one individual has now been expanded to include numerous malacologists who have made significant contributions to the field.

In November, 1978, I personally interviewed Dr. Joseph Bequaert in Tucson, Arizona and in four days obtained approximately eight hours of tapes. In June, 1979, I recorded approximately 13 hours of tapes with Dr. William J. Clench in Boston, Massachusetts. Other persons will be recorded as time and money are available.

The rights to all tapes are signed to me for the purposes of developing the history of malacology, but eventually I will donate the tapes (cassettes and reel to reel) to the Archives of the American Malacological Union for future use by malacologists and historians.

A CLASSIFICATION OF THE MOLLUSKS USED FOR GRAVE DECORATION IN CENTRAL TEXAS

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ABSTRACT

During the 19th and early 20th century the practice of incorporating marine and freshwater mollusk shells in grave decoration was popular among the German and Mexican populations of Central Texas. Studies have identified 4 styles of shell decoration. This work identifies the species used, relates the history and possible origin of the practice and illustrates the status of the graves today.

CONSERVATION OF NON-MARINE MOLLUSCS IN TEXAS STATE PARKS

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ABSTRACT

The major threat facing Texas non-marine molluscs is the ubiquitous loss of habitat. Terrestrial and aquatic gastropods are subject to little substantive collecting pressures. Fresh-water mussels are collected on a local level as seed for the Japanese pearl oyster industry.

Statutory protection of non-marine molluscs is limited to pelecypods. However, all plants and animals in Texas State Parks are protected from collection except by permit. Permits of this type are gratis but should be justifiable via scientific purposes.

A number of restricted and declining non-marine molluscs such as the snail (*Stenotrema leai cheatumi*) in Palmetto State Park occur within the boundaries of various state parks.

HELICINA ORBICULATA IN WELDER WILDLIFE FOUNDATION, SAN PATRICIO COUNTY, TEXAS

Adelaide Johnstone
Corpus Christi Museum
Corpus Christi, TX 78412

THE FRESHWATER MUSSELS OF THE NAVASOTA RIVER, TEXAS¹

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ABSTRACT

From September 1972 to May 1975, 1,318 freshwater mussels were collected from 37 stations along the Navasota River, Texas, a tributary of the Brazos River. Seventeen species representing two families, six subfamilies, and 13 genera were collected. Six of the 17 species are reported for the first time from the Navasota River.

Analysis of the distribution of the freshwater mussels reveals that they are confined essentially to one of three distinct divisions of the Navasota drainage, the main channel, the tributaries, and the impoundments. Further analysis shows that the amblemid subfamily Ambleminae is indicative of the main channel fauna, and the unionid subfamilies Pleurobeminae and Lamsilinae are indicative of the tributaries and impoundments respectively.

The Amblemididae make up only 29.4% of the species present but 52.6% of the total number of individuals collected. *Ambelma plicata* was the most common species present, accounting for 26.1% of the individuals collected. The Unionidae account for 70.6% of the species collected and 47.4% of the individuals.

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MOLLUSCAN DISTRIBUTION IN COPANO BAY, TEXAS¹

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ABSTRACT

Benthic samples from Copano Bay, Texas, were collected on a 1-mi grid in March and April, 1976. Seventy-four molluscan species, including 33 pelecypods, 40 gastropods, and 1 scaphopod were taken from 93 stations in Copano Bay. Molluscan distribution was correlated with gross sediment, salinity, feeding type, and total organic carbon content. Seven sediment types were mapped in Copano Bay. The mud and sand end members had fewer molluscan slive individuals whereas the muddy sands has the highest number of live individuals.

Fourteen of the 25 living molluscan species were euryhaline marine and could tolerate the highly variable salinities. Many dead stenohaline species were found: only one was live.

The two most abundant feeding types, the deposit and suspension feeders, numerically dominated in the muddy sands and muddy shells, respectively. Generally, stations with a high total organic carbon content also had a large population of deposit feeders, although there were some exceptions.

Extensive *Crassostrea virginica* reefs are present in Copano Bay. Whole shells or fragments of oyster shell were found in 75 percent of the samples, and six stations had live *Crassostrea*. *Odostomia impressa* and *Ischadium recurvum* were the predominant mollusks at the reef stations.

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FRESHWATER

NOTES ON THE SOUTH AMERICAN ACARINE GENUS ATACELLA: MITE PARASITES ALSO OCCURRING IN NORTH AMERICAN FRESH-WATER MUSSELS

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ABSTRACT

Several species of the nominal genus *Atacella* (Arthropoda: Acarina: Unionicolidae) are to be reported as parasites of North American mustelacean and unionacean fresh-water mussels (Mollusca: Bivalvia). New information on the systematics of these mites and their fresh-water mussel hosts was presented.

NOTES ON THE REPRODUCTIVE BIOLOGY OF GLEBULA ROTUNDATA (LAMARCK) (BIVALVIA: UNIONIDAE: LAMPSILINAE)

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ABSTRACT

Studies of *Glebula rotundata* in a south central Louisiana canal (Bayou Peyronnet, St. Martin Parish) revealed that most female mussels were reproductively inactive during the coolest months (October-February) exhibiting barren and thin marsupia. Immediately prior to the charging period, however, the marsupia, though still empty were inflated and firm. Fertilization and subsequent marsupial charging occurred in late February and early March: this coincided with a substantial increase in water temperature. Larvigerous individuals were first collected in early April, implying an approximate thirty day development period. The highest percentages of larvigerous females were noted in May and July. Females apparently recharge soon after completion of glochidial discharge, thus initiating another period of gravidity. Evidence suggesting a multiple gravidity sequence during the reproductive season includes: a) non-gravid females collected after March generally exhibited inflated but

gravidity sequence during the reproductive season includes: a) non-gravid females collected after March generally exhibited inflated but flaccid marsupia (many had very small pockets of glochidia in the distal most portions of the "ovisacs") or inflated but firm marsupia (similar to those described for precharging individuals); b) cyclic changes in the proportions of larvigerous, ovigerous, and non-gravid females throughout the reproductive season; and c) occurrence of ovigerous females in April-August collections (zygotes, 2-16 celled embryos, and blastula stages were noted).

Glebula rotundata exhibits a reproductive sequence that is atypical of those observed thus far in the Lampsilini: 1. most female *Glebula* are barren during cool months and gravid in the warm months, the reverse is generally observed in other lampsilines and 2. *Glebula rotundata* apparently has a multiple "tachytictic" breeding strategy rather than the single "bradytictic" cycle observed in other Lampsilini.

ANODONTA AND LAMPSILIS AT LOCH RAVEN RESERVOIR

Glenn A. Long

Sunrise Foundation, Inc.

ABSTRACT

This presentation summarizes a six-year informal study of unionid populations at Loch Raven Reservoir, an impoundment of the Gunpowder Falls in Baltimore County, Maryland, which serves as Baltimore's principle source of drinking water. Data are presented in two parts: one regarding the variety of specimens collected, the other pertaining to naiad living habits.

Species represented in the study group are *Anodonta cataracta*, Say 1817; *A. imbecillis*, Say 1829 and *Lampsilis radiata radiata* (Gmelin 1791). Ten observations are itemized and briefly discussed regarding the diversity of molluscan living habits as they were affected by various environmental changes in the reservoir.

NOTE ON THE TAXONOMY AND SYSTEMATIC OF SOME UNIONACEA FROM THE PANUCO RIVER DRAINAGE IN MEXICO, AND THE WESTERN DRAINAGE OF TEXAS

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ABSTRACT

General systematic, taxonomic, and biogeographic remarks are drawn from anatomical observations of several taxa of fresh-water mussels (Bivalvia: Unionacea) from predominantly montane portions of the Panuco River drainage in San Luis Potosi and Tamaulipas, Mexico: certain unionaceans from the western drainage of Texas are discussed as well.

RECENT CORBICULA IN NORTH AMERICA

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ABSTRACT

The Columbia and the Colorado River systems contain the Chinese species *C. fluminalis*. It has been found in the Upper Rio Grande. *Corbicula leana* Prime is from the Bay area of California. All other records from the U.S. are *C. leana* Prime, carried eastward by fishermen.

THE OSPHRADIA OF A FRESHWATER BIVALVE: HISTOLOGICAL EVALUATION AND FUNCTIONAL CONTEXT

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ABSTRACT

Recent studies indicate that the osphradia are confined to the suprabranchial shelf of the animal, in close association with the ventral surface of the visceral ganglion and with the excurrent siphon. In *Corbicula* (Bivalvia: Sphaeriacea) osphradia are paired and comprised of (1) extensively innervated osphradial epithelium; (2) dozens of unmyelinated nerve fibers which course along the base of the osphradial epithelium in lieu of a basement membrane; and (3) clusters of neurons whose processes are associated ventrally with the osphradial epithelium and dorsally with the visceral ganglion.

Review of the literature indicates there has been widespread misunderstanding among other investigators who have commonly assumed (a) the bivalve osphradia to be associated with the incurrent siphon rather than with the excurrent siphon of the animal; (b) the bivalve osphradia are oriented just the inverse of the actual position delineated in this study; and (c) the bivalve osphradia function as a "scent organ" and/or as a particle-size detector. Findings presented by this author indicate that the foregoing assumptions may be largely incorrect, and that the role of the bivalve osphradia is more likely to be that of an "eye" than a "nose."

THE SPECIES PROBLEM IN CAMPELOMA (GASTROPODA: VIVIPARIDAE)

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ABSTRACT

Very little is actually known about the North American viviparid genus *Campelema* Raf. 1819 even though it is a relatively common snail in freshwaters east of the Great Plains. Species, vaguely described on the basis of shell characteristics, are poorly delineated from one another. Most of this alpha taxonomy occurred prior to 1900, and a subsequent analysis of the genus using current perspectives is lacking. The number of species comprising the genus and their respective geographic ranges are not definitely known.

The problem of species identification is three-fold. First, the strong reliance on shell characters to define species has often assumed that most shell variation is genetic and ignored the probability of environmentally induced variation. Second, no serious attempt has yet been made to discover other (i.e., anatomical, ecological) species specific characteristics to augment the original descriptions. The few existing anatomical studies have provided such generalized descriptions that it is impossible to make any valid species comparisons. And, thirdly, the fact that reproduction can occur either parthenogenetically or sexually, depending on the species/population, further complicates the problem of species delineation.

Preliminary observations on *Campelema* from Georgia and Florida suggest that populations in this region may be ideal for comparative studies on genetic vs. environmental variation in shell morphology, anatomy, and parthenogenetic vs. sexual reproduction. Although only 2 species, *C. geniculum* and *C. limum* (includes *C. floridense*) are reported from this region, the appearance of the shell is highly variable among all populations, even within the same drainage. Initial dissections of specimens suggest the possibility that species specific characteristics will be found upon careful examination of the nervous, reproductive and excretory systems. Both *C. geniculum* and *C. limum* allegedly reproduce sexually, but populations of parthenogenetic *Campelema* sp. are common in the Southeast. In some cases the parthenogenetic and sexual populations are adjacent, separated by no readily apparent barrier. Brood production appears to follow the same basic seasonal pattern in all the southeastern *Campelema* populations. However, certain characteristics of the brood seem to be correlated to the method of reproduction. Parthenogenetic females tend to mature younger and have larger broods than equivalent sized sexually reproducing females. Malformed young, including those with reversed symmetry, are common in broods of parthenogenetic females but absent in broods of sexual females.

AN ELECTROPHORETIC AND SHELL MORPHOMETRIC SURVEY OF GONIOBASIS FROM THE UPPER NEW RIVER AND SURROUNDING DRAINAGES

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ABSTRACT

Three species of the freshwater snail genus *Goniobasis* are widespread in creeks and small streams of the upper New River in Virginia and North Carolina, *G. proxima*, *G. semicarinata*, and *G. simplex*. But they do not occur in the main river, and thus their ranges are fragmented into small isolates. Eight sample sites were established in the New River drainage, and one site each in the Roanoke, Smith, Yadkin, and Holston, to assess the effects of this isolation.

Starch gel electrophoresis was used to examine allelic frequencies at

15 enzyme loci for 50 individuals from the 12 populations. A matrix of Nei's genetic distances (D) was then used to perform a multi-dimensional scaling. Electrophoretically, the three species are quite distinct. There are also great differences between conspecific populations. The average Nei's identity (I) for conspecific populations was .89, a normal value for subspecies of other animals. Most of this difference was due to fixation of alternate alleles. Heterozygosity (H) averaged over the 12 populations was 1%, an extremely low value.

Seven shell characters were measured on 20 individuals from each population. A multi-dimensional scaling was performed on the 12 populations, based on the means of the seven characters and Sokal's measure of taxonomic distance. The three species were fairly distinct, but one *G. proxima* population could not be distinguished from *G. simplex* on the basis of shell morphology. It is suggested that the colonization of a hardwater stream by the normally softwater-dwelling *G. proxima* allowed this population to develop a larger, heavier shell and come to resemble the hardwater-dwelling *G. simplex*.

The hardwater *G. proxima* population has diverged more from conspecific populations in both shell morphology and isozyme frequency than any other population surveyed. If divergence is measured as euclidean distance to species centroid after multi-dimensional scaling, electrophoretic divergence is correlated to divergence in shell morphology at the 95% confidence level (Spearman rank correlation coefficient = .70).

BITHYNIA TENTACULATA – A REPLACEMENT FOR NORTH AMERICAN PLEUROCERID SNAILS?

Suzanne Hamilton

Department of Zoology, University of Maryland
College Park, MD 20742 ABSTRACT

Endemic pleurocerids in North America have disappeared where *Bithynia tentaculata* (Linnaeus), an immigrant gastropod from Europe, was introduced. *Bithynia* now occurs in the Potomac River among populations of *Mudalia carinata* (Bruguiere) and *Goniobasis virginica* (Gmelin). A study of egg productivity in field populations revealed that the presence of *Bithynia* snails and eggs on rocks that serve as oviposition sites significantly reduced egg densities of both *Goniobasis* and *Mudalia* when compared with relative egg densities where pleurocerid species occurred together or alone. *Bithynia* egg masses dominated the total area of common oviposition sites and where egg densities were high, *Bithynia* egg capsules covered those of pleurocerids.

Bithynia was more resistant to desiccation in the field, produced a larger hatchling, possessed a higher intrinsic rate of increase (r) and higher individual reproductive effort (measured as average dry weight of eggs/lifetime/average dry weight of adult female) than either pleurocerid species. These last two traits suggest that *Bithynia* has the highest potential for rapid population expansion.

Mudalia and *Goniobasis* were less susceptible to local crayfish predators that attack gastropod shell and were more tolerant to rapid river currents than *Bithynia*. In the Potomac River at Great Falls, Virginia where rapid waters and crayfish predators are present, all three species appeared to coexist.

APPLICATION OF MOLLUSCICIDAL DATA TO A WATER QUALITY PROBLEM WITH THE APPLE SNAIL

Marc J. Imlay

Columbia National Fisheries Research Laboratory
Columbia, Missouri 65201 ABSTRACT
Parley V. Winger

Field Research Station, University of Georgia
School of Forest Resources, Athens, GA 30602

The authors needed to evaluate the toxicity to apple snails (*Pomacea paludosa*) of copper compounds. This species is the sole food item of the endangered Everglade kite.

It was considered likely that information generated by investigators attempting to control snails might be useful to investigators attempting to protect snails.

CEPHALPODS

THE CHROMATIC, POSTURAL AND MOVEMENT COMPONENTS OF BODY PATTERNING IN THE SQUID *LOLIGO (DORYTEUTHIS) PLEI*.

Roger T. Hanlon

The Marine Biomedical Institute, University of Texas Medical Branch
200 University Blvd., Galveston, TX 77550 ABSTRACT

The tropical arrow squid *Loligo (Doryteuthis) plei* Blainville (1823) is neritic in habit and is distributed along the east coast of the American continents from North Carolina, throughout the Gulf of Mexico and Caribbean Sea, to Brazil. In a laboratory study the behavior of 400 live squids (size range 3 to 285 mm mantle length) was found to be associated with specific body patterns. Body patterns were categorized as either acute or chronic, depending upon their duration; they are produced by combinations of the 13 chromatic, 6 postural and 5 movement components. The chromatic components predominate and are most important. They are produced by the reflective iridophores and by the selective innervation of groups of chromatophores, and they include: *Clear*, *All dark*, *Ring*, *Accentuated testis*, *Shaded testis*, *Dorsal stripe*, *Arm spots*, *Stitchwork fins*, *Mid-ventral ridge*, *Lateral flame*, *Lateral blush*, *Tentacular stripe* and *Dorsal arm iridophores*. Postural components include: *Bottom sitting*, *Two raised arms*, *Four arm upward curling*, *Downward curling*, *Downward V curl* and *Downward curling into mantle*. Movement components include: *Parallel positioning*, *Fin beating*, *Forward rush*, *Chase* and *Flee*.

The most common chronic (long lasting) body patterns are *Clear*, *Ring*, *Dorsal stripe* and *Shaded testis*, and they all appear to aid in camouflage against the bottom. The most common acute (short duration) patterns are *All dark*, *Ring*, *Accentuated testis*, *Shaded testis* and *Downward curling*. Males are more aggressive and are capable of a wider range of patterns than females.

Situation analyses indicate that specific patterns coincide with particular aspects of behavior and can be used to distinguish calmness, stress, aggression, mating behavior and sex of individuals. Although the body patterns have only been viewed in an intraspecific context, *Loligo plei* appears to have a more colorful behavioral repertoire than other members of the same genus.

SCHOOLING BEHAVIOR OF THE SQUID *LOLIGO OPALESCENS*

Ann C. Hurley

Moss Landing Marine Laboratories
Moss Landing, CA ABSTRACT

The squid *Loligo opalescens* forms schools which are similar in many respects to those of obligate schooling fishes. These schools have parallel orientation of individuals and strong cohesiveness. Laboratory experiments indicate that the main sensory modality regulating schooling is vision, and that school structure can be modified by environmental conditions.

EXPERIENCE IN COMMERCIAL DEVELOPMENT OF A SQUID FISHERY

Warren F. Rathjen

National Marine Fisheries Service, P.O. Box 1109
Gloucester, MA 01930 ABSTRACT

Worldwide demand for cephalopod products has accelerated harvest of the octopus, squid and cuttlefish resources adjacent to continental masses. In the northwest Atlantic utilization of squid resources began to increase about ten years ago.

Two varieties of squid – the long-finned squid *Loligo pealei* and the short-finned squid *Illex illecebrosus* are aggressively harvested. Much of the fishing is conducted by large stern trawl vessels which freeze the squid for later sale in international markets. Some harvesting is done with "jigs," and small amounts are landed by traps and other methods.

Experimentation with light attraction has been underway on a limited basis. New trawling techniques have also been attempted. Handling,

processing, and marketing studies have been undertaken with varying results.

An intensification of biological studies has been initiated by state, university, federal and independent researchers. In addition, joint research is underway or contemplated with a host of foreign interests. Included are Canadian and U.S. cooperation with Japanese, Polish, Soviet, Spanish, East and West German and others.

Transfer of technology and innovation are integral parts of a developing fishery. Basic research in biological and other aspects are also increasingly important.

CEPHALPOD RESOURCES IN THE INDO-WEST PACIFIC

Clyde F.E. Roper & Michael J. Sweeney

Department of Invertebrate Zoology,

National Museum of Natural History

Washington, D.C. 20560

ABSTRACT

The fishery resources of squids, cuttlefishes, octopuses, and *Nautilus* are surveyed throughout the area from India, Southeast Asia, and West Pacific. Topics include: currently utilized species, potentially useful species, fishery techniques and landings, distributions, and biological aspects.

A LARGE SCALE REARING EXPERIMENT ON HATCHLINGS OF THE SQUID *LOLIGO OPALESCENS*

BERRY, 1911

Won Tack Yang, Mark E. Krejci, William H. Hulet

Roger T. Hanlon and Raymond F. Hixon

The Marine Biomedical Institute, University of Texas Medical Branch

200 University Blvd., Galveston, TX 77550 ABSTRACT

Although squids of the genus *Loligo* have well-established commercial and scientific value, none of the many attempts to raise them to maturity have succeeded. We are currently rearing the California market squid, *Loligo opalescens*, in closed systems using artificial seawater maintained at about 16°C and 36 ppt salinity. At this writing six squids (estimated mantle length 40-60 mm) are alive at day 183 from an initial population of 860 hatchlings.

For the first five months we cultured the squids in a 1500 l. circular rearing tank that was connected to an 1100 l. water conditioning tank equipped with water cooler and biological, chemical and physical filters. Thereafter the squids were moved to a 4000 l. raceway 9.1 m long and 1.8 m wide linked to an adjoining 1100 l. conditioning tank.

Two peaks in mortality occurred, one between days 1-20 and another at days 45-73, and were attributed to fin damage and food inadequacy. Growth of healthy animals was best described by the exponential curve $y = 2.7187e^{0.0175t}$ ($r^2 = 0.9968$) where y = mantle length and t = age in days. Growth rates determined from measurements of dead squids range between 0.1 and 8.2 mm/month.

Squid hatchlings were fed wild-caught copepods (primarily *Acartia tonsa*) the first 69 days. Subsequently we fed the squids different foods as they increased in size: brine shrimp, *Artemia salina* (days 3-66); mysids and postlarvae of shrimp, *Penaeus* spp. (days 59-84); mysids, *Mysidopsis* spp. (days 45-131); fishes, *Fundulus similis* (days 102-126) and *Menidia beryllina* (days 122-177); and grass shrimp, *Palaemonetes pugio* (days 130-183). Only live, moving prey were accepted as food. All wild-caught foods were treated with either quinacrine, erythromycin or tetracycline for infections or parasites prior to feeding.

Schools of five to six squids were first observed on day 79 when they were 5-12 mm mantle length. We have seen very little intraspecific aggression and have observed that the body patterns of young squids are composed of eight chromatic and three postural components. The major aspects of this experiment were documented in a 16 mm color film.

GROWTH OF *OCTOPUS JOUBINI* ROBSON, 1929 REARED IN CLOSED SEAWATER SYSTEMS

John W. Forsythe

The Marine Biomedical Institute, University of Texas Medical Branch

200 University Blvd., Galveston, TX 77550 ABSTRACT

Twenty individual pygmy octopuses, *Octopus joubini*, were reared

from eggs to maturity on a diet of live crabs in closed natural seawater systems. The culture systems consisted of rectangular 80 and 150 l. all-glass aquaria having crushed oyster shell filter beds, side-mounted auxiliary filters (containing polyester fiber and activated carbon) and protein skimmers. The seawater was continuously subjected to biological, chemical and mechanical filtration with pH ranging from 7.58 to 8.00 and ammonia (NH_3) and nitrite (NO_2) levels never exceeding .004 mg/l. and .198 mg/l., respectively. Periodic water changes helped maintain nitrate (NO_3) levels at or less than 40 mg/l. Water temperature was kept at 25°C and salinity at 34-36 ppt.

Twenty octopus hatchlings less than 24 hours old were randomly selected and placed in individual rearing chambers supported in the aquaria. Each octopus was fed a single live crab (*Uca* spp.) per day. Crabs were weighed before feeding and uneaten exoskeletons were collected and weighed to estimate daily food intake. At two to four week intervals the octopuses were narcotized in a 1.5% solution of ethyl carbamate in seawater, weighed and measured. There was 85% survival of sexual maturity (18 to 22 weeks). During the first 4 weeks growth rates were highest and averaged 7.39% increase in body weight/day. The exponential growth curve for this period was best fit ($r^2 = .9963$) by the equation: $\text{wet weight} = .033e^{.074t}$, where t = age in days. Beyond 4 weeks growth rates steadily declined to approximately 2% increase in body weight/day at 24 weeks. The growth curve during this period of logarithmic growth was best fit ($r^2 = .9914$) by the equation: $\text{wet weight} = 9.48 \times 10^{-5} e^{.231t}$. Female octopuses grew slightly faster than males and attained a larger size at maturity. Mean gross growth efficiency (GGE) over 24 weeks was 35.9%. Mean GGE for females was slightly higher (38.0%) than that of the males (34.5%).

PIPELAGIC CEPHALOPODS FROM THE EQUATORIAL ATLANTIC

Charles E. Lea

Dept. Oceanography, Texas A&M Univ.

College Station, TX

ABSTRACT

Pelagic cephalopods were identified from open midwater trawls taken in the Equatorial Atlantic. Specific captures are discussed with regard to vertical distribution, seasonal differences and zoogeographic distribution. Sampling problems are reviewed.

RELATIONSHIPS WITHIN THE LOLIGINIDAE (CEPHALOPODA) AS SHOWN BY THE COMPARATIVE MORPHOLOGY OF THEIR HECTOCOTYLI

Thomas F. Brakoniecki

Univ. of Miami RSMAS, Miami, FL

ABSTRACT

From observations and measurements made on 31 species of squid from the family Loliginidae, their hectocotyli are divided into 7 basic morphological types. The relationships between the species contained within these types are discussed using available zoogeographic information in addition to the comparative morphological data.

ON BEING BIG OR LITTLE IN CEPHALOPODS

Gilbert L. Voss

RSMAS, Univ. of Miami, Miami, FL

ABSTRACT

Maximum and minimum sizes are given for both decapods and octopods, and the role of large and small forms in the food chain is discussed. *Architeuthis* and *Idiosepius* in decapods show a range of from 20 m to 16 mm, while *Octopus* ranges from 9 m to 20 mm.

OSMOTIC CONCENTRATION CHANGES IN THE BAY SQUID *LOLLIGUNCULA BREVIS* (BLAINVILLE, 1823)

AT VARIOUS SALINITIES

Joseph P. Hendrix, Jr.

The Marine Biomedical Institute, University of Texas Medical Branch

200 University Blvd., Galveston, TX 77550 ABSTRACT

The genus *Lolliguncula* is unique among squids in that it is generally reported in low salinity waters. The physiological characteristics allowing this unusual occurrence are as yet unknown. Trawl captured *Lolliguncula brevis* from Galveston Bay, Texas were held in large closed system laboratory aquaria to determine osmotic concentration changes in the

squid after acclimation to low salinity seawater. Comparative measurements of hemolymph and ambient seawater osmotic concentrations were made in squid acclimated to 18, 28 and 36 ppt natural seawater. The hemolymph osmotic concentration of *L. brevis* remains isosmotic or slightly higher than its seawater environment throughout the measured range. Equilibration to reduced salinity environments is a relatively rapid process, requiring 3 to 4 hours for 95 percent acclimation to a 10 ppt salinity reduction (30 to 20 ppt) with isosmotic concentration reached in 36 hours.

This marine euryhaline cephalopod can survive in aquaria at salinities down to 17 ppt for two weeks. The squid exhibited unusual behavior during rapid salinity changes. When salinity was slowly lowered to 15 ppt the squid showed signs of stress immediately, with 100 percent mortality occurring in the following 48 hours.

THE "MACROTRITOPUS PROBLEM" SOLVED:
OCTOPUS DEFILIPPI RAISED FROM

A WILD-CAUGHT, PELAGIC MACROTRITOPUS

Roger T. Hanlon, Raymond F. Hixon and John W. Forsythe

The Marine Biomedical Institute, University of Texas Medical Branch
200 University Blvd., Galveston, TX 77550 ABSTRACT

The previously unknown identity of the distinctive pelagic octopod "Macrotritopus larva" characterized by long third arms has been determined to be *Octopus defilippi* Verany, 1851 by rearing a wild-caught Macrotritopus to sexual maturity in the laboratory. Macrotritopus has been reported throughout the subtropical and tropical Atlantic and Mediterranean but the adult form was uncertain. We observed several Macrotritopus and caught seven (mantle lengths 7-15 mm) during underwater night light stations we performed at 15-40 m depth during a saturation dive mission in NOAA's NULS-1 underwater habitat located in St. Croix, U.S. Virgin Islands.

In midwater, drifting octopuses spread their very long arms out in a vertically oriented fan, but feeding was not observed. When pursued, they swam backwards by jet propulsion, in some instances to the bottom where they crawled in a coordinated manner into the first hole they encountered. It is possible that they are benthic by day and pelagic by night.

We transported two live Macrotritopus via air to Galveston, Texas and placed them in a closed artificial seawater system consisting of two 150 l. glass aquaria, one functioning as the maintenance chamber and the other as the filtration and water conditioning system. Temperature was maintained at 25°C and the salinity was kept between 32-35 ppt. Two 50% water changes were made to reduce nitrate accumulation.

We reared one female octopus from 10 to 90 mm mantle length in 151 days on a diet of live fiddler crabs (*Uca* sp.). For the first four weeks the octopus buried itself in the oyster shell substrate except during foraging and feeding; thereafter it hid in empty shells. She maintained a nocturnal activity pattern that became less pronounced with age. On day 143 she laid over 10,000 unfertilized eggs, mean length 2.1 mm, which she carried in her arms for 8 days until death. The octopus showed a wide range of body patterns that were composed of 12 chromatic, 6 textural and 9 movement components. This specimen has been deposited in the National Museum of Natural History, Division of Molluscs (USNM 730019), Washington, D.C.

SYMPOSIUM: MOLLUSCS OF THE GULF OF MEXICO

Organizer: T.E. Pulley, Director
Houston Museum of Natural History
P.O. Box 8175, Houston, TX 77004

THE SHALLOW WATER MARINE MOLLUSCAN FAUNAS OF THE YUCATAN PENINSULA

Harold E. Vokes

Dept. of Geology, Tulane University
New Orleans, LA 70118

ABSTRACT

The Yucatan Peninsula, flanked on the east by the Caribbean Sea and on the north and west by the Gulf of Mexico, possesses varied ecologic environments including mangrove swamps, sand beaches, rocky shores, coral reefs and atolls. Fifteen years of collecting has yielded a fauna of 826 molluscan species.

REPORT ON THE NORTHWEST GULF OF MEXICO MOLLUSK POPULATION SURVEY

Constance E. Boone

3706 Rice Blvd.

Houston, TX 77005

ABSTRACT

The Northwest Gulf Mollusk Population Survey was begun in 1965 by Harold Geis, geologist and amateur conchologist. It now consists of over 22,000 lots obtained by dredging and grab, diving from U.S. destroyers, and beach collecting. It is expected that 1500 species will be represented, with many new records for the Gulf and some new to science. The material is being monographed in a continuing series by Dr. Helmer Ode in the *Texas Conchologist*, quarterly issued by the Houston Conchology Society, Inc. The survey material has been donated to the Houston Museum of Natural Science where it is being cataloged. Malacologists are invited to use the material for research. Contact Dr. T.E. Pulley, director of HMNS.

FOUR NEW RECORDS OF APLOCOPHOROUS MOLLUSKS FROM THE GULF OF MEXICO

Granvil Treece

University of Texas Marine Science Institute

Port Aransas, TX

ABSTRACT

One hundred thirty four specimens of Aplacophorous mollusks from 95 samples ranging from 42 to 134 meters depth along the south Texas continental shelf are reported. Until now, there have been no known records of these in the Gulf of Mexico. Descriptions and scanning electron micrographs of the animals are given.

SUBMERGED BANK AND CORAL REEF MOLLUSKS OF THE WESTERN GULF OF MEXICO

John W. Tunnell, Jr.

Biology Department, Corpus Christi State Univ.

Corpus Christi, TX 78411

ABSTRACT

Studies on the ecological and geographical distribution of submerged bank and coral reef mollusks in the western Gulf of Mexico have revealed distinct populations with respect to depth, substrate, habitat, and latitudinal locations. A slightly depauperate molluscan fauna is characteristic of southwestern Gulf reefs, whereas a mixed Carolinian-Caribbean fauna is common on offshore Texas banks.

MOLLUSCS OF THE PUNTA DEL MORRO-PUNTA DELGADA
REGION VERACRUZ, MEXICO

Ronald C. Circe, George N. Wiley, and John W. Tunnell Jr.
P.O. Box 6010 #339 Corpus Christi State University
Corpus Christi, TX 78411

ABSTRACT

The molluscan fauna of the Punta del Morro-Punta Delgada region, located approximately 75 km north of Veracruz, was studied during August, 1976, and March and October, 1977. One-hundred twenty-one species (55 alive) consisting of 80 Gastropoda, 36 Pelecypoda, 3 Polyplacophora, and 2 Cephalopoda were collected or observed from the volcanic rocky shores of this region.

THE IMPORTANCE OF SPIRAL SCULPTURE AND
THE LARVAL SHELL IN TURBONILLA

(PYRAMIDELLIDAE, GASTROPODA) SYSTEMATICS
Eric N. Powell and Howard Spero

Department of Oceanography, Texas A&M University
College Station, TX 77843

ABSTRACT

Intraspecific variability in axial and spiral sculpture patterns makes species identification difficult.

The difficulties encountered stem more from the paucity of interspecific variation in spiral sculpture patterns rather than any excess of intraspecific variation present. Many species possess minor variants on the same spiral banding theme.

The shape and size of the larval shell has proved to be particularly useful in species identification. The larval shell, for example, shows a relatively small intraspecific variability in size, whereas the interspecific variability in size is substantial. A careful documentation of the inter and intraspecific variation in spiral sculpture patterns plus the utilization of other characters such as the larval shell have provided sufficient information to consistently distinguish between the six species of pyrgiscoids examined.

MOLLUSCS OF SHELF-EDGE SUBMARINE BANKS
IN THE NORTHWESTERN GULF OF MEXICO

James C. Woods & John W. Tunnell Jr.

Padre Island National Seashore, 9405 S. Padre Island Dr.
Corpus Christi, TX 78418

ABSTRACT

A total of 265 (29 alive) species of molluscs representing 88 families were identified from sediment samples collected on twelve shelf-edge submarine banks in the Northwestern Gulf of Mexico. One hundred and seventy-five of the species were micro-molluscs. Zoogeographic affinity of 159 species was determined by examining the distributional records.

*SYMPOSIUM:
THE LIFE HISTORIES OF MOLLUSKS

Organizers: David R. Lindberg and Michael G. Kellogg

*Abstracts of this symposium are being published by the Western Society of Malacologists

The population dynamics of the bivalves *Solen rosaceus* and *Tagelus californianus* in a natural and thermally altered environment in South San Diego Bay. *Jose-Maria Merino.*

Micro-acoustic and microscopic observations on the utility of marine grazing Molluscs introduced to grow on submerged structures for the biological control of marine fouling. *Christopher L. Kitting.*

Maximum size and latitude: their relation in *Littorina planaxis* and *L. sitkana*. *Peter Frank.*

Protoconchs, eggs and veligers of eastern North American odostomoid pyramidellids. *Robert Robertson.*

Reproductive dynamics in *Cyanoplax dentiens* (Gould), a brooding hermaphroditic chiton. *David R. Lindberg and John S. Pearse.*

Reproductive biology of *Arthritica crassiformis* Powell and *Arthritica bifurca* (Webster), two commensal bivalve Mollusks (Leptonacea). *Paul Chanley and Matoira Chanley.*

The removal of *Ostrea lutaria* and *Ostrea chilensis* from the genus *Ostrea* on the basis of larval characteristics. *Paul Chanley.*

Life history of *Epitonium tinctum* (Prosobranchia: Mesogastropoda). *Amy Breyer.*

Reproduction in the nudibranch *Spunilla neapolitana*. *Linda S. Eyster and Kevin Eckelbarger.*

Reproductive biology of *Modulus modiolus* Linnaeus (Prosobranchia: Centriacea). *Richard S. Houbnick.*

Sexual phases and planktonic larval development of *Crassostrea virginica* Gmelin from coastal lagoons of southeast Mexico. *Antonio Garcia-Cubas, Patricia Rogers, Emilia Chevez.*

Sexual maturity, embryonic and larval development of the brackish water clam, *Rangia cuneata* from the Terminos Lagoon, Campeche, Mexico. *Antonio Garcia-Cubas, Emilia Chavez, Patricia Rogers.*

Preliminary results of a study of the life history of the brackish water snail *Tryonia imitator* (Pilsbry). *Michael G. Kellogg.*

Life history evolution in temporary versus permanent ponds: *Lymnaea palustris* and *L. stagnalis*. *Kenneth M. Brown.*

Geographical distribution of breeding systems in freshwater bivalves of Eastern North America. *Gerald Summers.*

Aspects of early development in a land snail, *Anguispira alternata*. *Carl W. Gugler.*

AMU ANNUAL REPORTS

AMU ANNUAL BUSINESS MEETING

August 9, 1979
Corpus Christi, Texas

President William E. Old, Jr., called the general business meeting of the Forty-Fifth session of the American Malacological Union to order at 2:30 p.m. in La Sala Grande of La Quinta Royale Motor Inn at Corpus Christi, Texas, on August 9, 1979.

Minutes of the 1978 meeting as printed in the 1978 Bulletin were approved.

Corresponding Secretary Paul Jennewein was not in attendance due to illness. No report was available. (Report as sent later printed below.)

Constance E. Boone, Recording Secretary, summarized membership for the last fiscal year, noting to members that there had been a decrease for the second year and pointing out the need to encourage new members. She did announce that new members had been enrolled at this meeting and that there were several student memberships added recently. Report approved and is printed in full below.

Treasurer Myra Taylor summarized her report and asked that members note that the accounting was for the fiscal year of 1978. Report approved and printed below in full.

The Recording Secretary gave a summary of the Publications' Report prepared by Editor Dee Dundee, stating that the 1978 Bulletin had been published for \$1,652.05 under budget. Since the Newsletters had not been Xeroxed as mandated, the cost of printing the Newsletters was approximately \$600.00, \$100.00 over budget. Summary approved.

A motion brought from Council requested the approval of the expenditure of \$20.00 for the membership fee for the Editor to the Council of Biological Editors. Approved.

Dr. Harold Murray reported that the auditing committee had found the books in good order. Approved.

Dr. Clyde F.E. Roper presented the budget for 1980 approved by Council. As voted by the membership, it is as follows:

INCOME

Memberships (all types except life)	\$7,247.00
Sales:	
HTCS	300.00
Rare & Endangered Species Symposium	10.00
Bulletin, Back Issues	150.00
Teskey Index	50.00
Bulletin, Reprints	
(no longer through AMU treasurer)	0.00
Subtotal sales:	(\$510.00)
Page Charges to Authors	\$1,100.00
Proceeds of Meeting	200.00
Donations	100.00
Miscellaneous	20.00
TOTAL	\$9,177.50

Interest, savings, not added to income

DISBURSEMENT

Bulletin	\$4,500.00
Newsletters	750.00
Conservation Committee	200.00
Membership Committee	25.00

President's Organizing Fund	500.00
California Filing Fee	5.00
Officers to Meetings	800.00
Legal Defense	50.00
Postage (except Bulletin & Newsletters)	400.00
Printing (except Bulletin & Newsletters)	250.00
Office Supplies	50.00
Postal Permit	40.00
Miscellaneous	150.00
Annual Meeting Expense	150.00
Ads of Meeting & HTSCS, etc.	500.00
Membership WSM	7.50
Symposia subsidies	500.00
Student Prize (paper)	100.00
Editor's Expense	200.00
Teskey Index (no further cost)	0.00
TOTAL	\$9,177.50

Dr. Roper reported that the 1980 meeting would be held at Louisville, Kentucky, with the Louisville Conchological Society as host organization. The Forty-Sixth Annual Meeting will be held at the Executive Motor Inn July 19-24. Symposia on the feeding mechanisms of mollusks and the functional morphology of Cephalopods are planned. There will be a book auction. Entertainment includes a paddle boat trip on the river, and there will be field trips for fresh water, terrestrial and fossil mollusks. Report approved.

Dr. Richard Houbrick reported no site had been found for the 1981 meeting. He promised to inform the members about the selection of the site as soon as possible. It was announced that 1981 would be the fiftieth anniversary of the American Malacological Union. The first organizational meeting had been held in Philadelphia, PA., and there was the hope expressed by members that the 1981 meeting could be there.

Dr. George Davis's report on the financial picture for AMU pointed out the need to raise dues. A motion from Council to raise dues, starting with the next fiscal year beginning January 1, 1980, was approved as follows:

Individual dues will be \$10.00 annually; corresponding members' dues will be \$10.00 annually, plus postage; affiliate membership for institutions, shell clubs, corporations, etc., will be \$13.00 annually, and the price of subscription for nonmembers will be \$13.00 annually.

The slate of officers to be elected at this meeting and approved by Council was announced as follows:

President	Dr. Clyde F.E. Roper	One Yr.
President-Elect	Dr. Richard Houbrick	One Yr.
Vice-President	Dr. Louise Russert	
	Kraemer	One Yr.
Recording Secretary	Mrs. Constance E. Boone	Three Yrs.
Councillors-at-Large	Dr. Virginia Vail	Two Yrs.
	Mrs. Florence Kuczynski	Two Yrs.

Motions and Resolutions voted at the open conservation meeting held on Monday of this annual meeting had been sent to Council too late to be considered by Council at the luncheon meeting on Wednesday. Since the Executive Council Chairman on Conservation was not present, Council asked a committee of Council members to consider the measures and report to the general meeting. All the motions received approval to be sent to

Dr. Arthur Clarke, Executive Council Chairman on Conservation, for action for AMU. They are as follows:

1. To endorse the recommendation of Arthur H. Clarke, Chairman of the Executive Committee on Conservation, for cooperative preparation of a new "Red Book" for the preservation of additional endangered or threatened species of mollusks.

2. That the letter from Lawrence Jerome regarding the decline of East Coast marine mollusks be referred to R. Tucker Abbott.

3. That the outline by Paul and Paula Mikkelsen for data by collectors and/or observers be sent to members to encourage record keeping. (To cut costs this would be put in the Fall Newsletter).

4. That material on the development/preservation of the Currituck Outer Banks, North Carolina, be sent to the North Carolina Shell Club for monitoring and appropriate action.

The following resolutions, approved at the general meeting of conservation on Monday, received approval from the Executive Committee acting for Council to be sent to Dr. Arthur Clarke to provide whatever appropriate action needed for AMU:

1. Because we are aware of the existence of many unique freshwater mussel and snail species in the Appalachicola River basin; and

Because we are aware that a significant oyster and other food fishery occurs in Appalachicola Bay; and

Because we understand that the Governors of the States of Alabama and Georgia have outvoted the Governor of Florida on an agreement to develop the Appalachicola, Chattahoochee, and Flint Rivers into barge canals, which will undoubtedly adversely affect the fauna of both the rivers and the bay;

BE IT RESOLVED by the members of the American Malacological Union that our President write letters to the Governors of Alabama, Florida, and Georgia, to the senators from these states, and to other appropriate Federal officers and agencies, expressing our opposition to this proposed development of the Appalachicola, Chattahoochee, and Flint Rivers, and asking that each of the states and agencies take appropriate action to preserve or enhance the natural character of these rivers and the unique fauna, including mollusks, which the rivers and basins contain.

2. Because of the apparent continued plans for more development of the Marco Island area in Florida by the Deltona Corporation;

BE IT RESOLVED by the members of the American Malacological Union that our President (or his designate) should reaffirm and reinforce the previous position of this Union in opposition to the permit applications of Deltona Corporation for further development at Marco Island.

3. To Mr. Robert W. Knecht, Assistant Administrator, Office of Coastal Zone Management, 3300 Whitehaven Street, N.W., Washington, D.C. 20235:

Because a species of brachiopod, *Crania californica* S.S. Berry and a clam, *Dimya coralliotis* S.S. Berry, have been taken only once and the singularly important key to molluscan evolution, *Vema (Laevipilina) hyalina* McLean, also occurs only there and in a very limited patches, these being matters of special concern to the members of this Union,

and because the survival of these and other animals and associations of great importance to marine scientists is at stake,

the American Malacological Union in formal session asks renewed and careful examination of the biota of the Cortes-Santa Rosa Ridge of the Pacific Outer Continental Shelf and the reinstatement of active marine sanctuary procedures for the areas already shown to have species that are rare and endangered,

namely the mollusks and brachiopods cited above, the foraminiferans, and the coral, *Allophora*.

Noting that you have stated that the Bureau of Land Management has legal powers to protect this area, we point out that enforcement is delegated to a staff already over-burdened in its task of protecting desert areas from vandalism. We call on you and on all other responsible officials to provide real protection for the organisms of the Pacific Outer Continental Shelf.

4. Because of the singularly unique assemblage of molluscan species in and around Lake Waccamaw, North Carolina; and

Because of the encroachment of land development around this fragile ecosystem;

BE IT RESOLVED by the members of the American Malacological Union that our President (or his designate) should reaffirm and reinforce our previous resolution to the Nature Conservancy, encouraging them to continue to acquire land around Lake Waccamaw, N.C. to enhance and preserve the rare and endemic fauna and flora of the basin, including several species of terrestrial and aquatic mollusks.

The Executive Committee considering the conservation motions and resolutions declined to act on Resolution 5 concerning the Tellico Dam Project.

Mrs. Smith Whiteside then made the motion that Resolution 5 be proposed to the general membership. This resolution reads as follows:

5. Because of the continuing decline in the numbers of free-flowing stream habitats for mollusks and other freshwater animals in the United States; and

Because of the continuing refusal of some members of the Congress of the United States and others to accept the fact that the Tennessee Valley Authority's Tellico Dam Project is economically unsound and is certain to destroy the only natural population of the Snail Darter, an endangered species; and

Because Congressmen John Duncan has added an amendment to the Federal Water Projects Appropriations Bill to exempt the Tellico Dam Project from ALL Federal regulations, to require the TVA to complete the project;

BE IT RESOLVED by the members of the American Malacological Union that our President and each one of us should write to the President of the United States and appropriate members of Congress, opposing the adoption of the Duncan amendment to the Federal Water Projects Appropriations Bill and, if the amendment is retained by Congress, to have the President veto this bill.

Dr. J.P.E. Morrison moved to amend this motion deleting the words "is economically unsound." Deletion approved.

Discussion followed, with Dr. Davis reviewing the Executive Council Committee on Conservation and its purpose. He pointed out that many of the actions of the general conservation committee could have been handled by the Executive Council Committee on Conservation but that at this meeting no member of the committee was present. He advised the motion on Tellico be killed and be passed on to the Executive Council Chairman for handling.

Since time was important for action on this Resolution, members expressed concern for AMU action. Dr. Alan Solem made the motion that the main motion be tabled. Seconded by Dr. Don Moore and approved. A ruling was then made by Dr. Solem and Dr. Harold Murray for Council that this tabling would hold only to the end of this annual meeting, the end of this session.

With the above ruling in effect, Dr. Davis then introduced a motion that the chairman of the executive committee on conservation pursue Resolution 5 to conclusion within a 45 day period of this meeting in order to expedite the question at hand. This

motion was amended to make the period 30 days after this annual meeting. The amended motion received approval.

Several members expressed concern for future AMU action on such a resolution, pointing out its effect on deep water mollusks.

Dr. William Clench reported that he had permission to deposit a copy of a historical film of an early AMU meeting in Maine in the AMU Archives. The Archives are now safely in position at the Academy of Natural Sciences at Philadelphia, PA.

Dr. Davis reported a successful meeting of the AMU Council of Systematic Malacologists had been held on Monday of this session and announced that AMU had been voted into membership in the Association of Systematics Collections.

The report from the advisory committee to the president and president-elect on upgrading AMU meetings to encourage professional participation and consideration of amateur members resulted in two motions from Council as follows:

A. AMU will invite each shell club affiliate to send a representative to the annual meeting who will be registered at a reduced fee. AMU will provide special recognition for such a representative.

B. AMU, under the direction of the President, will have daily, informal, concurrent sessions for the amateur on diverse topics of interest to the amateurs, to be presided over by one or two specialists.

Both motions won approval.

President Old announced the guidelines for the student award initiated at this annual meeting as follows:

1. The student must be a bonafide student at the time of the meeting.

2. The student must be sole author of the paper considered for the award.

3. The student must designate which paper will be considered for the award if he gives two papers.

President Old announced that judges this year were Dr. Dorothea Franzen, Dr. Virginia Vail, Dr. William Clench, and Dr.

Richard Houbbrick.

John Henkinson rose to commend President Old for beginning this award for students.

A motion was brought from Council recommending that the Index to AMU Bulletins be offered for \$5.00 postpaid. Approved.

Discussion on the price of *How to Study and Collect Shells*, the popular booklet last printed in 1974 and offered for \$2.50, brought the explanation of the present policy to offer the booklet to anyone for regular bookseller's prices as announced in the Newsletters and the Bulletin.

There was some discussion on timing the annual meeting to coincide with other meetings for those interested in mollusks. There was also a comment by Harold Lewis, councillor-at-large, that AMU had its own unique character and that it should continue to maintain its own policies on meetings. He offered to work with anyone wishing to initiate special finances to bring in speakers or enlarge the scope of meetings.

Dr. Louise Russert Kraemer made a motion for AMU to accept the offer from the Association of Systematics Collections to provide the mechanism of obtaining at reduced prices some books and materials on mollusks. This was seconded by John Jenkinson. Discussion brought forth the comments from Council members that they felt that volunteer officers of AMU who would have to handle the sales of such publications through AMU for AMU members would involve time that such volunteers might not have. The motion was not approved.

Dr. Murray asked approval to send greetings to the honorary president, honorary members, a past officer and two ill members not able to attend this meeting. Approved.

The meeting was adjourned at 4 p.m.

Respectfully submitted,
Constance E. Boone
Recording Secretary

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING DECEMBER 31, 1978

CHECKBOOK BALANCE, JANUARY 1, 1978

\$ 2,715.15

RECEIPTS:

Memberships:

Regular	3,789.39	
Sustaining	64.00	
Corresponding	163.00	
Clubs & Institutions	874.50	
Subscribing	121.00	5,011.89

Sales:

HOW TO STUDY AND COLLECT SHELLS	307.82	
RARE AND ENDANGERED SPECIES	5.00	
TESKEY INDEX	45.50	
BULLETIN, Back Issues	120.00	478.32

Page Charges To Authors

Donations (From Dues Notices)

Transfer from Savings Account to Checking Account

1,178.86	
170.50	
500.00	1,849.36

Total Receipts From All Activities

7,339.57 7,339.57

TOTAL CASH ACCOUNTED FOR:

10,054.72

DISBURSEMENTS:

BULLETIN, Printing, Postage, Etc.	3,184.15		
NEWSLETTERS, Printing, Postage, Etc.	496.45		
Conservation Committee	46.09		
President's Expenses	44.28		
California Filing Fees	15.00		
Membership Dues, W.S.M.	15.00		
Officers' Expenses To Meeting	929.28		
Other Postage	297.41		
Other Printing	253.79		
Office Supplies	48.81		
Miscellaneous Expenses, including Refunds Of Dues Overpayments & Bank Charges	122.57		
Transfer of Excess Funds to Savings	1,000.00		
Total Disbursements From All Activities		6,452.83	6,452.83

CHECK BOOK BALANCE ON DECEMBER 31, 1978

			3,601.89
TOTAL CASH ACCOUNTED FOR DURING 1978			10,054.72

SASA* Savings Acct. #5-034514	2,223.11		
Transferred to Checking Account	-500.00		
Transferred From Checking To Savings	1,000.00		
Interest Added	234.59		
Total For Account #5-034514		2,957.70	
SASA* Savings Certificate #5-904812 (Life Membership Funds)	2,274.61		
Interest Added	152.76		
Total For S.C. #5-904812		2,427.37	
TOTAL SAVINGS		5,385.07	

*SASA = San Antonio Savings Association

RECAPITULATION OF ASSETS, DECEMBER 31, 1978:

Cash in Checking Acct., Mercantile Bank	3,601.89
Treasurer's Petty Cash	25.00
Secretary's Petty Cash	125.00
SAS* Acct. #5-034514	2,957.70
TOTAL ASSETS	6,709.59
LIFE MEMBERSHIP SAVINGS CERTIFICATE #5-904812	-2,427.37

4,282.22

A.M.U. NET WORTH, DECEMBER 31, 1978

CHANGES IN CAPITAL ACCOUNT:

AMU Capital Account, January 1, 1978	2,813.65
AMU Capital Account, December 31, 1978	4,282.22
NET INCREASE IN ASSETS IN 1978	1,468.57

Respectfully Submitted,
Myra L. Taylor
Treasurer

REPORT FROM THE RECORDING SECRETARY

Membership decreased again in 1978. The account of membership for the fiscal year of 1978 is as follows:

Honorary Life President	1	Regular Members	
Honorary Life Members	8	(All Western Hemisphere)	482
		Additional Family Members	82
		Foreign Corresponding Members	17
		Affiliated Members (Institutions)	
		Domestic	36
		Foreign	13

Clubs, regional organizations, corporations, etc.	41
Life Members	28
	Total
Subscriptions for Bulletin Only	708
	7

The total figure of 708 membership is 52 less than the total figure of 760 for 1977. For the second year in a row we show a decline in membership. The decrease of 52 in 1978 remains after tallying formal resignations and deaths, recording new members and removing names for non-payment of dues.

As noted to Council before, we lose approximately ten percent of membership each year. The loss has to be made up by adding new members. Last year we did not add enough new members to make up for the loss which did run somewhat higher than ten percent.

By June 15, 1979, we had enrolled and reinstated 76 new members for 1979. This is very good. I wish to note that officers and other Council members, as well as some of our other members and shell club affiliates, have helped to encourage memberships. This, it seems to me, is the best way to acquire members who will become long-time members of this organization. We also note that a number of the new members are students and young professionals in the field of malacology.

Expenses for this office in 1978 were \$156.55. This is a low

figure for operating costs. The 1979 figure will be higher due to extra postage costs and the need for new supplies. Postage costs involve answering all inquiries on membership and enrolling new members, as well as mailing back Bulletins, copies of Endangered Species Symposium and Index ordered. Newsletters and Bulletins returned to me with changes of addresses supplied by the Post Office are remailed to members. It cost AMU 92¢ to accept the returned 1978 Bulletin, and each returned Newsletter cost 25¢. We then resend these to the member at additional cost well above this original permit mailing. While I do ask for postage from members for rerouted mail we do not have a set fee for such remailing and only sometimes get additional postage.

Therefore, it is exceedingly important to keep the mailing list as correct as possible, even if it means updating it during the year for each mailing. I note that President William E. Old, Jr., had only one return on the first class mailing for the annual meeting this year. The mailing list had been updated by me for this mailing. We urge members and clubs to send changes of addresses during the fiscal year to avoid return and rerouting of mail. The address labels will again be made by this secretary for each mailing.

Reimbursement for attending the Wilmington meeting was set at \$250.00 by this secretary.

Respectfully submitted,
Constance E. Boone

REPORT FROM THE CORRESPONDING SECRETARY

One hundred seventy-seven copies of *How to Study and Collect Shells* were sold and delivered, with \$300.32 received, in 1978.

Work on promoting the AMU meeting held at Wilmington, N.C., in 1978 included sending out copy to magazines and newspapers.

Letters sent to me concerning questions on mollusks and about AMU are answered.

Copies of the gift books offered new members, courtesy of Dr. R. Tucker Abbott, were mailed during 1978. The bonus copies of *American Malacologists* are no longer available.

Respectfully submitted,
Paul R. Jennewein
Corresponding Secretary

THE AMERICAN MALACOLOGICAL UNION, INC.

Active Members 1979

Membership List Revised Nov. 1, 1979

Abbott, Dr. R. Tucker, P.O. Box 2255, Melbourne, FL 32901.
Adler, Dr. Howard, 116 Edgewood Drive, Bridgewater, N.J. 08807 (Marine-radiography).
Aguayo, Dr. Carlos G., Dept. of Biology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708.
Alarcon, Benito F., Corro, Isla de Pascua, Chile (Easter Island mollusks).
Albert, Mr. and Mrs. Ernest, 905 S. Bayshore Blvd., Safety Harbor, FL 33572.
Alexander, Robert C., 423 Warwick Rd., Wynnewood, PA 19096.
Allen, James E., 1108 Southampton Dr., Alexandria, LA 71301 (Tertiary micro-mollusca).
Allen, Dr. J. Frances, 7507 23rd Ave., Hyattsville, MD 20783.
Allen, Mr. and Mrs. Lawrence K. (Betty), Box 822, Port Isabel, TX 78578 (*Murex*, *Pecten*, world marines; owners, Shop of the Seven Seas).

Allen, Miss Letha S., 187 Argyle St., Yarmouth, Nova Scotia, Canada B5A 3X2 (General).
Amaratunga, Tissa, Dept. Fisheries and Oceans, Resource Branch, Box 550, Halifax, Nova Scotia, B3J 2S7, Canada (Life history, biology and management of Cephalopods).
Anders, Kirk W., Shells of the Sea, Inc., P.O. Box 1418, Ft. Lauderdale, FL 33302 (Volutidae, all rare shells).
Anderson, Carleton Jay Jr., 56 Kettle Creek Rd., Weston, CT. 06883.
Andrews, Dr. Jean, 241 Melrose, Corpus Christi, TX 78404.
Armington, Mr. and Mrs. Stewart F. Jr., 15932 Brewster Rd., Cleveland, OH 44112 (*Cypraea* of Australia).
Ashwell, James R., 2125 Mohawk Trail, Maitland, FL 32751 (General).
Atheam, Herbert D., Museum of Fluvial Mollusks, Rt. 5, Box 499, Cleveland, TN 37311 (Freshwater mollusks).
Atheam, Mrs. Roy C., 5105 N. Main St., Fall River, MA 02720 (Land shells).
Austin, Lyn Michele, 9401 Roberts Dr., 20-C, Atlanta, GA 30338.

- Avellanet, Mrs. Helene, 105 Clipper Way, Fair Winds Villas, Nokomis, FL 33555.
- Avery, Mrs. R. Gail, Box 2557, Harbor, OR. 97415 (West American mollusks; exchange).
- Babrazai, Mr. Noorullah and Dr. Sianoosh Sam Sam, Dept. General Biology, Univ. of Arizona, Tucson, AZ. 85721.
- Baerreis, David A., 1233 Sweet Briar Rd., Madison, WI. 53705 (Paleoecological interpretation through mollusks).
- Bailey, Dr. Joshua L. Jr., 4435 Ampudia St., San Diego, CA. 92103.
- Baker, Mrs. Horace B., 11 Chelton Rd., Havertown, PA. 19083.
- Baker, John A., 147 Hedgegrove Ave., Satellite Beach, FL. 32937 (General).
- Baker, Sam, Candi, Jeffrey and Ryan, 1530 Astec Circle, Naperville, IL. 60540 (Collecting cones and cowries).
- Barlow, Mrs. G. Barton, 76 Westervelt Ave., Tenaflly, N.J. 07670.
- Barr, John W., Jr., 312 Windward Dr., League City, TX. 77573 (*Cypraeidae*).
- Bates, Dr. John M., 1900 Dexter Ave., Ann Arbor, MI. 48103.
- Bauer, Laura M., 2126 45th St., Galveston, TX. 77550 (All mollusks).
- Baum, Newman N., 83 Weaving Lane, Wantagh, L.I., N.Y., 11793.
- Bazata, Kenneth R., Hazleton Environmental Sciences, 4010 NW 39th St., Bldg. 1374, Lincoln, NB. 68524 (Terrestrial pulmonates; *Dentalium*).
- Bearse, David T., 300 S. Van Dorn St., R 313, Alexandria, VA. 22304 (Fisheries biologist).
- Beetle, Ms. Dorothy E., Muscogee Planetarium, 2900 Floyd Rd., Columbus, GA. 31907 (U.S. land and fresh water mollusks).
- Bequaert, Dr. Joseph C., 102 S. Sherwood Village Drive, Apt. 227, Tucson, AZ. 85710.
- Bereza, Daniel J., 825 N. 24th St., Philadelphia, PA. 19130 (Unionidae; Pleuroceridae).
- Bergmann, Joseph A., Rt. 3, Box 3064, Boerne, TX. 78006 (Land and freshwater mollusks, recent and fossil).
- Berke, Ian, 4032 23rd St., San Francisco, CA. 94114.
- Berry, Dr. Elmer G., 8506 Beech Tree Court, Bethesda, MD. 20034.
- Berry, Dr. S. Stillman, 1145 W. Highland Ave., Redlands, CA. 92373.
- Bianchi, Mrs. Ann, Box 235, Goodland, FL. 33933.
- Biasca, Mrs. Cynthia, 5811 Cheena, Houston, TX. 77096.
- Bickel, David, 613 W. Ave. C, Bismarck, N.D. 58501 (Systematics and ecology of freshwater mollusks, esp. Pleurocerid snails).
- Bijur, Jerome M., 135 Seventh Ave. N., Naples, FL. 33940 (Buy, exchange Florida, Caribbean and Gulf of Mexico marine).
- Bippus, Mr. and Mrs. Alvin C., 2743 Sagamore Rd., Toledo, OH. 43606 (Marine gastropods).
- Bishof, David, 215 35th Ave., North, St. Petersburg, FL. 33704.
- Bishop, Thomas Dale, Dept. of Biology, Univ. of Southwestern Louisiana, Lafayette, LA. 70504 (Ecology related to gastropods).
- Bleakney, Dr. J. Sherman, Dept. of Biology, Acadia Univ., Wolfville, Nova Scotia, Canada BOP 1X0 Nudibranchs and sacoglossans; ecology, zoogeography, systematics).
- Bledsoe, William D., 352 Bon Hill Rd., Los Angeles, CA. 90049.
- Body, Ralph L., 2538 10th Ave. W., Seattle, WA. 98119.
- Bogan, Arthur E., Research Ass't Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916.
- Boone, Mr. and Mrs. Hollis Q., 3706 Rice Blvd., Houston, TX. 77005.
- Borror, Kathy Gail, OSU, Museum of Zoology, 1813 N. High St., Columbus, OH. 43210.
- Boss, Dr. Kenneth J., Museum of Comparative Zoology, Harvard Univ., Cambridge, MA. 02138.
- Bottimer, L.J., Rt. 1, Box 205, Tow, TX. 78672 (recent and fossil mollusks).
- Boyd, Dr. and Mrs. Eugene S., 6806 Gillis Rd., Victor, N.Y. 14564 (All aspects of Phylum Mollusca).
- Brakoniecki, Thomas F., RSMAS, 4600 Rickenbacker Causeway, Miami, FL. 33149 (*Cephalopoda*).
- Brandauer, Mrs. Nancy E. and Mr. Carl M., 1760 Sunset Blvd., Boulder, CO. 80302.
- Branson, Dr. Branley A., P.O. Box 50, Eastern Kentucky Univ., Richmond, KY. 40475.
- Bratcher, Mrs. Twila, 8121 Mulholland Terrace, Hollywood, CA. 90046.
- Brice, James R., 121 N. California Ave., Mundelein, ILL. 60060.
- Britton, Dr. Joseph C., Dept. of Biology, Texas Christian Univ., Ft. Worth, TX. 76129.
- Brooks, Jane M., 3050 Sunrise Blvd., Ft. Pierce, FL. 33450.
- Brown, Drs. Harvey and Marjorie, 9455 S.W. 81st Ave., Miami, FL. 33156.
- Broyles, Mrs. Ralph E., 5701 Fairfield Ave., Ft. Wayne, IN. 46807.
- Brunson, Dr. Royal Bruce, 1522 34th St., Missoula, MT. 59801.
- Buchanan, Alan, Missouri Dept. of Conservation, Fish & Wildlife Research Ctr., 1110 College Ave., Columbia, MO. 65201 (Fisheries biologist).
- Buckley, George D., 164 Renfrew St., Arlington, MA. 02174.
- Buerk, Dr. Minerva S., Maybrook Chalet, 331 Penn Rd., Wynnewood, PA. 19096 (Anatomy, histology).
- Buffet, Miss Sydney, 41 Stratford Ave., Pittsfield, MA. 01201.
- Bullis, Harvey R., Jr., P.O. Box 490409, Key Biscayne, FL. 33149.
- Burch, Mrs. Beatrice L., P.O. Box 309, Kailua, HI. 96734 (Dredging).
- Burch, Dr. John B., Museum of Zoology, University of Michigan, Ann Arbor, MI. 48104 (Land and fresh water mollusks).
- Burch, Mrs. John Q., 1300 Mayfield Rd., Apt. 61-L, Seal Beach, CA. 90740.
- Burger, Sybil B., 3700 Gen. Patch N.E., Albuquerque, NM 87111 (Gulf of Mexico; land snails).
- Burke, Mrs. Patricia, 18128 Lakeside Lane, Nassau Bay, TX. 77058.
- Burky, Dr. Albert J., Dept. of Biology, Univ. of Dayton, Dayton, OH. 45469.
- Calnan, Thomas R., Univ. of Texas Bureau of Economic Geology, University Station Box X, Austin, TX. 78712 (Gulf Coast mollusks).
- Campbell, Mrs. Minnie Lee and Donald C., 3894 DuPont Circle, Jacksonville, FL. 32205 (General).
- Cantera, Sr. Jaime Ricardo, Universidad del Valle, Dept. de Biología, A.A. 2188, Cali, Colombia (ecology, taxonomy).
- Capo, Thomas R., 59 Nickerson St., Falmouth, MA. 02540 (Benthic ecology).
- Cardeza, R. Adm. and Mrs. Carlos M. Dec. to Mar. 29, P.O. Box 6746, Houston, TX. 77005; April 1 to Nov. 30, 1718 Jewel Box Dr., Snabel, FL. 33957 (Florida and Texas shells).
- Cardin, Charles, 12571 S.W. 268 St., Naranja, FL. 33032 (Ovulidae, registered shell dealer).
- Carlton, James T., Woods Hole Oceanographic Institution, Woods Hole, MA. 02543 (estuarine and brackish water mollusks).
- Camey, Dr. W. Patrick, Box 2, NAMRU 2, Jakarta, APO San Francisco, CA. 96356.
- Carriker, Prof. Melbourne R., College of Marine Studies, Lewes Complex, Univ. of Delaware, Lewes, DE. 19958.
- Carroll, Susan E., 32-03 150 St., Flushing, N.Y. 11354 (Parasitology in marine mollusks).
- Carson, John and Laura W., 221 Elm Ave., Morrisville, PA. 19067.
- Castagna, Michael, Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Pelecypod larval behavior).
- Cate, Mr. and Mrs. Crawford N., P.O. Drawer 710, Rancho Santa Fe, CA. 92067 (*Mitra*, *Cypraea*; no exchanges).
- Cetnar, Dr. and Mrs. Eugene J., 4379 Ramsgate Lane, W. Bloomfield, MI. 48013.
- Chace, Emery P., 24205 Eshelman Ave., Lomita, CA. 90717.
- Chadwick, Albert F., 2607 Tumer Rd., Wilmington, DE. 19803 (Marine mollusks).
- Chanley, Mr. and Mrs. Paul, Proyecto Hatchery, Fundacin Chile y Universidad del Norte, Casilla 281, Coquimbo, Chile.
- Chappell, Mrs. Elaine, 2435 Dunloe Drive, Dallas, TX. 75228 (All mollusks).
- Charbonneau, Roger, 100 East Prieur St., Montreal, Canada H3L 1C9.
- Chichester, Lyle F., Dept. Biol. Sciences, Central Conn. State College, 31 Chamberlain St., New Britain, CT. 06052 (Ecology of terrestrial gastropods, biology of land slugs).
- Christensen, Carl C., 1612 Kamole St., Honolulu, HI. 96821.
- Christie, Dr. John D., Dept. of Pathology, Univ. of Texas Medical Branch, Galveston, TX. 77550.
- Chrosiecowski, Przemyslaw K., APTDO 125, Maracay, Venezuela, 3KO (Planorbidae).

- Clark, Miss Violette W., 1706 Lincoln Rd., Champaign, ILL. 61820.
- Clarke, Dr. Arthur H., Dept. of Mollusks, USNM, Smithsonian, NHB-E 514, Washington, D.C. 20560.
- Clench, Dr. William J., 26 Rowena St., Dorchester, MA. 02124.
- Clover, Philip W., P.O. Box 83, Glen Ellen, CA. 95442 (Rare *Cypraea*, *Conus*, *Voluta*, *Murex*, *Marginella* – Buy and exchange).
- Clymer, George M., 378 Quinell Ave., Lakeland, MN. 55043 (Unionidae).
- Coan, Dr. Eugene V., 891 San Jude Ave., Palo Alto, CA. 94306.
- Cohen, Anne C. (Mrs. Daniel M.), 6803 Florida St., Chevy Chase, MD. 20015 (Loliginidae; *Litiopa melanostoma*).
- Coleman, Dr. Richard W., Dept. of Biology, Prof. of Science and Head, Upper Iowa University, Fayette, IA. 52142 (Environmental interrelationships, plants-invertebrates).
- Colmenares, Raul Peraza, Lra transversal de Sebucan, Quinta "Don Raul", Caracas, Venezuela, Apartado Postal 80.659 (Environmental impacts).
- Compitello, Mrs. Juliette, 5630 Alta Vista Rd., Bethesda, MD. 20034.
- Conde, Vincent, McGill University (Redpath Museum), Montreal, Canada 110.
- Coney, Cliff, 2008 Canterbury Rd., Kingsport, TN. 37660 (Grad student at East Tenn. State Univ., investigating niche partitioning by the terrestrial mollusca of the Ridge and Valley Province of southeastern Tenn.).
- Cook, Dr. Susan B., Dept. of Zoology, The Ohio State University, 1735 Neil Ave., Columbus, OH. 43210 (Behavioral ecology of tropical marine gastropods; behavioral ecology of freshwater gastropods).
- Cooper, Robert W., 5012 Pfeiffer Rd., Peoria, IL. 61607 (Florida marine; *Murex*, *Pecten*, *Spondylus*, SCUBA).
- Corgan, Dr. James X., Dept. of Geography and Geology, Austin Peay State Univ., Clarksville, TN. 37040 (Microscopic gastropods).
- Cornely, Guy, 53 rue Jean-Jaures Raizet, Abymes, Guadeloupe, French West Indies.
- Cosman, Dieter, 7 Oak Hill Rd., Huntington, N.Y. 11743 (Marine tropical and subtropical Gastropoda and Bivalvia worldwide).
- Counts, Clement L., III, College of Marine Studies, University of Delaware, Lewes, DE. 19958 (Zoogeography, taxonomy).
- Courtney, Charles M., director, MAMES, 990 N. Barfield Dr., Marco Island, FL. 33937 (Aquatic ecology/malacology).
- Craine, Mrs. Ruth A., P.O. Box 2001, Southern Pines, NC 28387.
- Cramer, Frances L., 766 Obispo Ave., Long Beach, CA. 90804 (Ecology: conservation).
- Crissinger, Myrna May, 820 N. Court St., Crown Point, IN. 46307.
- Croft, Mrs. Thomas L., 9393 Ladue Rd., St. Louis, MO. 63124 (Marine; fossils).
- Cull, Mr. and Mrs. Robert R., 7927 Chippewa Rd., Brecksville, OH. 44141.
- Cummings, George P., Jr., 815 Cedar Oak Lane, Harker Heights, TX. 76541 (Taxonomy, speciation, intraspecific variation).
- Cummings, Raymond W., 37 Lynaces Blvd., Fayetteville, NY. 13066 (West Indies shells, esp. Windward and Grenadine Is.).
- Cutler, Mr. and Mrs. Henry H., 105 Abbott Rd., Wellesley Hills, MA. 02181.
- Cvancara, Dr. Alan Milton, Dept. Geology, Univ. of N. Dakota, Grand Forks, ND. 58202 (Pleistocene and Holocene continental mollusks, early Tertiary continental and marine).
- D'Aluto, Mrs. John, Rt. #2, Box 65-J, West Highway 44, Wildwood, FL. 32785.
- Danforth, Louise L., 2529 Terry Lane, Sarasota, FL. 33581.
- Darcy, George H., Univ. of Miami Sch. of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Davenport, Mrs. Lillian B., 802 Cape Ave., Box 81, Cape May Point, NJ. 08212 (Conchology, malacology, pertaining to the sea).
- Davis, Dr. Derek S., Nova Scotia Museum, 1747 Summer St., Halifax, NS, B3M 3A6 Canada (Gastropod biology and taxonomy).
- Davis, Dr. George M., Academy of Natural Sciences of Philadelphia, 19th and the Parkway, Philadelphia, PA. 19103.
- Davis, Dr. John D., 25 Old Homestead Rd., Westford, MA. 01886 (Ecology of marine bivalves).
- Deatrick, Paul A., 218 S.W. 32 Ave., Miami, FL. 33135 (*Strombus*, *Busyscon*).
- de Blaisten, Dr. Lia O.B., Laboratorios Bioquímex, S.A. de C.V., Nicolas San Juan 1535, Colonia del Valle, Mexico 12, Mexico (Scientist amateur – American and Caribbean seashells; cowries and *Strombus*).
- de Graaff, Gemit, 10915 S.W. 55 St., Miami, FL. 33165.
- DeLuca, Mrs. John A. and Ms. Gladys DeLuca, 61 Deborah Rd., Hanover, MA. 02339.
- Demond, Miss Joan, 202 Bicknell Ave., #8, Santa Monica, CA. 90405.
- Dexter, Miss Norma, 150 Barker Hill Dr., RFD 3, Guildford, CT. 06437 (*Cypraea*).
- Dexter, Dr. and Mrs. Ralph W., Dept. Biological Science, Kent State Univ., Kent, OH. 44242.
- Dietrich, Mr. and Mrs. Louis E., 308 Veri Dr., Pittsburgh, PA. 15220.
- Dillon, Robert T., Jr., 155 B. Wilson Rd., Maple Shade, N.J. 08052.
- Dolin, Eric, 107 Briar Brae Rd., Stamford, CT. 06903 (*Conus*, *Cypraeidae*, *Strombus*, *Voluta*).
- Doyle, Miss Patricia, 336 Pine Ave., St. Lambert, Quebec, Canada J4P 2N8.
- Draper, Bertram C., 8511 Bleriot, Los Angeles, CA. 90045 (Eastern Pacific minute mollusks and all Western U.S. marine).
- DuBar, Jules R. and Susan S., Lakeview Hgts., Morehead, KY. 40351 (Cenozoic and recent mollusks, ecology and paleoecology).
- Dugdale, H.K., P.O. Box 1392, Wilmington, DE. 19899 (Editor, Chambered Nautilus Newsletter).
- Dundee, Dr. Dee S., Dept. of Biology, Univ. of New Orleans, Lakefront, New Orleans, LA. 70122 (Land mollusks, freshwater mussels).
- Dvorak, Stanley J., 3856 W. 26th St., Chicago, IL. 60623 (Muricidae).
- Eakle, Christine E. Rackey, William A., 2308 Breton Dr., District Heights, MD. 20028 (Worldwide collecting).
- Eddison, Grace G., M.D., "Wildwood," Rt. 4, Carlisle, KY. 40311.
- Edwards, Lt. Col. Corinne E., USAF (Ret.), P.O. Box 330691, Coconut Grove, FL. 33133 (*Chitons*, *Echinoids* – self-collected).
- Edwards, D. Craig, Dept. of Zoology, Morrill Science Center, Univ. of Massachusetts, Amherst, MA. 01003 (Population ecology and behavior of marine benthic molluscs).
- Elwell, Dr. Adela, Rt. 2, Box 268, Bemidji, MN. 56601 (Terrestrial gastropods).
- Elwell, Mrs. Marden F., 4 Crestview Dr., Cherry Hill, N.J. 08003.
- Emberton, Kenneth C., Dept. of Zoology/Microbiology, Ohio University, Athens, OH. 45701.
- Emerson, Dr. William K., American Museum of Natural History, Central Park West at 79th St., New York, NY. 10024.
- English, Rita C. and James F., 10300 Terrace Court, Parma, OH. 44130 (Fossils: Florida and Caribbean; ecology of mangrove areas).
- Erickson, Carl W., 4 Windsor Ave., Auburn, MA. 01501.
- Eubanks, Dr. Elizabeth R., 2162 E. Minton Dr., Tempe, AZ. 85282 (Florida marine shells).
- Evans, Roger, 1900 Camino de la Costa, Apt. 1, Redondo Beach, CA. 90277 (Diver; marine mollusks of Southern California).
- Evans, Miss Susan E., 244 Congress Ave., Lansdowne, PA. 19050 (*Conus*, *Cypraea*, *Murex*).
- Eversole, Dr. Arnold G., Dept. of Entomology and Economic Zoology, Clemson Univ., Clemson, SC. 29631. (Interpopulation variation and bioenergetics of molluscan populations.)
- Everson, Gene D., 100 North Holly Land, Plantation, FL. 33317 (Worldwide collection with emphasis on Florida, Caribbean and miniature).
- Fechtnr, Frederick R., 2611 W. Fitch Ave., Chicago, IL. 60645.
- Feinberg, Harold S., Dept. of Fossil and Living Invertebrates, American Museum of Nat. Hist., Central Park West at 79th St., N.Y., NY. 10024 (Land and freshwater mollusks).
- Ferguson, Dr. and Mrs. John H., 226 Glandon Dr., Chapel Hill, NC. 27514.
- Fieberg, Mrs. Kleinie, 1430 Lake Ave., Wilmette, IL. 60091.
- Fields, Mrs. Esther L., 1706 Lincoln Rd., Champaign, IL. 61820.
- Finlay, C. John, 116 Tanglewood Lane, Newark, DE. 19711 (Marine mollusks Western Atlantic and Caribbean).
- Foehrenbach, Jack, 91 Elm St., Islip Manor, NY. 11751 (Marine ecology).

- Fontanier, Charles E., P.O. Box 9325, Fort Worth, TX. 76107 (Cypraeidae, Unionidae; Scuba, Ecology).
- Foot, Miss Mary K., Apt. 418, 7201 Spencer Hwy., Pasadena, TX. 77505.
- Foster, Mrs. Fred H., 401 N. Justus St., Oxford, IN. 47971.
- Franzen, Dr. Dorothea, Illinois Wesleyan Univ., Bloomington, IL. 61701.
- Friedman, Myrna, 690 Hungry Harbor Rd., North Woodmere, NY. 11581 (Marine).
- Frye, Mark W., Dept. of Geology and Mineralogy, OSU, 125 S. Oval Mall, Columbus, OH. 43210 (Naïads, Micropaleontology with specialty in Ordovician micro-mollusks).
- Fuess, Thomas and Mrs. Mary Fuess, 6978 Pickadilly Ct. SW, Ft. Myers, FL. 33907 (Southwest Florida coast and Florida Keys mollusks).
- Fullington, Richard W. and Kate E., 215 Bonnie Brae, Denton, TX. 76201 (Land and freshwater gastropods of North America; curator, Invertebrate zoology, Dallas Museum of Natural History).
- Furbish, Dean R., 1977 Cambridge Dr., Apt. 1, Lexington, KY. 40504 (Behavior, physiology of mollusks).
- Gallardo, Lic. Ernesto Santos, Jorge Elliot #12, Colonia Polanco, 7º piso, Mexico, D.F.5.
- Gardner, L.E. (Lu), P.O. Box 92099, Milwaukee, WI. 53202.
- Gardner, Mrs. Sandra M., 1755 Univ. Ave., Palo Alto, CA. 94301 (Vermetidae).
- Garrett, Herman Benton II, Dept. of Biological Sciences, Univ. of New Orleans, New Orleans, LA. 70122 (Taxonomy of fresh water and land gastropods of the U.S.).
- Geller, Mrs. Leonard, 336 DeMott Ave., Rockville Centre, NY. 11570.
- Germer, John and Dorothy, 653 Briarcliff Ave., Maywood, NJ. 07607 (John: Photography of shells; Dorothy: *Pectens* and *Murex* and shells of the Eastern and Western Atlantic).
- Germon, Mrs. Raye N., 27 Rosemont Dr., Gaithersburg, MD. 20760 (Muricidae, Volutidae, Mesozoic and Paleozoic fossils marine).
- Gibbons, Mrs. Mary C., 5 Shady Tree Lane, Port Jefferson, Long Island, NY. 11777.
- Gilbert, Dr. William H., Dept. Biology, Simpson College, Indianola, IO. 50125 (Marine and freshwater bivalves – ecology, behavior, systematics; *Tellina*, *Macoma*).
- Gill, Richard W., Rt. #4, Charleston, IL. 61920 (Riverine Pelecypoda).
- Gilmour, Dr. Thomas H.J., Dept. Biology, Univ. of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0 (Ansimoyarian bivalves).
- Girardi, Dr. Elizabeth-Louise, 707 Kent Rd., Kenilworth, IL. 60043.
- Goethel, Lt. Col. (Ret.) and Mrs. Louis N., 9402 Nona Kay Dr., San Antonio, TX. 78217 (*Cypraea* – buy and trade).
- Gold, Albert, 118 W. 227 St., Bronx, NY. 10463.
- Goldberg, Richard L., 49-77 Fresh Meadow Lane, Flushing, NY. 11365 (Worldwide marine and land shells – collector and dealer).
- Golightly, Charles Grady, Jr., 1505 Lemon Tree Lane, College Station, TX. 77840 (Bivalve ecology/systematics).
- Gooch, Charles H., 611 E. Tuscaloosa St., Florence, AL. 35630.
- Goodfriend, Glenn A., Zoology Dept., Univ. of Florida, Gainesville, FL. 32611 (Molluscan ecology).
- Gordon, Mackenzie Jr., Paleontology and Stratigraphy Branch, U.S. Geological Survey, Smithsonian, Washington, D.C. 20560.
- Gordon, Mark E., Dept. of Zoology, Univ. of Arkansas, Fayetteville, AR. 72701 (Freshwater mollusks, Arkansas and mollusks of the Ozarks).
- Greenberg, Bayle, c/o Tidepool Gallery, 3907 W. 50th St., Edina, MN. 55424.
- Greenberg, Mrs. Janis, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greenberg, Mrs. Ruth, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Guckert, Richard H., 1757 Kimberly Dr., Marietta, GA. 30060 (Systematics of freshwater mussels; ecology; physiology of Nassariidae).
- Gudnason, 105 Danefield Place, Moraga, CA. 94556.
- Gugler, Dr. Carl W., School of Life Sciences, U. of Neb., Lincoln, NB. 68588 (Terrestrial pulmonates).
- Gunter, Dr. Gordon, Gulf Coast Research Lab., Ocean Springs, MS. 39564 (Ostreidae).
- Haage, Mrs. Daniel, 20 North Hill Rd., Wausau, WI. 54401.
- Haigh, Ernest S. and Marilyn E. and son, David, 6533 Orangewood Ave., Cypress, CA. 90630 (Worldwide seashells; trading and seashell stamps).
- Hall, Eleanor R., 1230 N.E. 88th St., Seattle, WA. 98115 (Marine gastropods, esp. worldwide *Cypraea*).
- Hall, Mrs. Warner L., 727 Queen's Rd., Charlotte, NC. 28207 (Self-collection, marine).
- Hamilton, Dr. Paul V., Assistant Professor, Biology, Univ. of W. Florida, Pensacola, FL. 32504 (Behavior and ecology of gastropods).
- Hamilton, Ms. Suzanne, 631 Blossom, Rockville, MD. 20850 (Freshwater gastropods).
- Hamilton, Mrs. William J. Jr., 615 Highland Rd., Ithaca, NY. 14850.
- Hand, Dr. Cadet H., Bodega Marine Lab, P.O. Box 247 Bodega Bay, CA. 94923.
- Hanley, John H., Branch of Paleontology and Stratigraphy, U.S. Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center, Denver, CO. 80225 (Taxonomy, paleoecology, biostratigraphy, and evolution of Mesozoic and Cenozoic nonmarine Mollusca).
- Hanlon, Dr. Roger T., UTMB-MBI, League Hall, R2, Galveston, TX. 77550 (*Cephalopods*).
- Hansen, William P., 315 West 102 St., N.Y., NY. 10025.
- Harasewych, Jerry, Delaware Museum of Natural History, Box 3937, Greenville, DE. 19807.
- Hargrave, Dr. David, Ass't Prof. Nat. Scs., College of Gen. Studies, Western Mich. Univ., 1104 Berkshire Dr., Kalamazoo, MI. 49007 (Collecting and photography).
- Harman, Dr. Willard N., State Univ. College at Oneonta, Oneonta, NY. 13825 (Fresh water mollusca).
- Harris, Ms. Bessie B.K., Rt. 8, Box 3, Lake City, FL. 32055.
- Harris, Don V. Jr., 4525 Glebe Rd. N., Arlington, VA. 22207.
- Harris, Mr. & Mrs. E. Milton, 3237 Carlisle Rd., Birmingham, AL. 35213.
- Harry, Dr. Harold W. and Dr. Mildred, 4612 Evergreen St., Bellaire, TX. 77401.
- Hartenstine, Raymond H., Biologist, 965 Belvoir Rd., Norristown, PA. 19401 (Fresh water malacology).
- Hartman, Joseph H., Dept. Geology/Geophysics, Univ. of Minn., 108 Pillsbury Hall, Minneapolis, MN. 55455 (Cretaceous-Eocene F.W. moll. of W. US; Viviparidae).
- Haskell, Mrs. William, 529 Via Lido Soud, Newport Beach, CA. 92663.
- Hausser, Penny H., 127 Godfrey Lane, Huntington, NY. 11743.
- Haven, Dr. Dexter S., 336 Lafayette Rd., Yorktown, VA. 23690 (*Mercenaria mercenaria*, *Mya arenaria*, *Crassostrea virginica*).
- Havlik, Mrs. Marian E., 1603 Mississippi St., LaCrosse, WI. 54601 (Naïads of Miss. River).
- Hazin, Hissa Mussa, R. Dr. Isaac Salazar No. 114, Tamarineira, Recife, Brazil (Basilian marine and foreign marine, conchological books).
- Hedges, Arlene J., 404 North East St., Crown Point, IN. 46307.
- Helms, Don R., Aquatic biologist, RR #3, Box 63, Bellevue, IO. 52031 (Special interest in Mississippi River).
- Hepler, Neil M. and Laura E., 435 S. Federal Highway, Deerfield Beach, FL. 33441 (Nautiloidea and *Nautilus*).
- Herly, Paul W. and Margaret, RD #1, Box 224, Swanton, N.J. 08210 (Paul: Fossil; Peg: *Cypraea*).
- Herr, Marion and Frank, 7901 Dewitt Dr., Baldwinsville, NY. 13027.
- Hershler, Robert, Dept. of Earth and Planetary Science, The Johns Hopkins Univ., Baltimore, MD. 21218 (Ecology and anatomy of hydrobiid snails).
- Hettick, Mrs. G. Riley, 933 Lynnwood Dr., Bartlesville, OK. 74003.
- Hickey, Ms. Mary T., 4415 Independence St., Rockville, MD. 20853 (Scallops).
- Hickman, Dr. Carole S., Dept. of Paleontology, Univ. of Calif., Berkeley, CA. 94720 (tertiary molluscan paleontology).
- Hickman, Mrs. Harriette L., 20 Wilkie Blvd., Beesley's Point, Marmora, NJ. 08223 (Worldwide *Epitonium*).
- Hickok, George H., 27 Whitney Circle, Windsor, CT. 06095 (amateur).
- Hicks, Mr. and Mrs. Edwin S., 1522 Palmwood Dr., Eau Gallie, FL. 32935 (Recent and fossil marine shells of Western Atlantic).
- Higbee, Ms. Florence and Dr. Joan Higbee, 13 North Bedford St., Arlington, VA. 22201.
- Hillman, Robert D. Ph.D., Battelle-Clapp Laboratories, Duxbury, MA. 02332 (Molluscan ecology and physiology).

- Hixon, Raymond F., UTMB-MBI, League Hall, R2, Galveston, TX. 77550 (*Cephalopods*).
- Hoagland, Dr. K. Elaine, Dept. of Biology, Lehigh Univ., Bethlehem, PA. 18015.
- Hobbs, Sue, P.O. Box 153, Cape May, NJ. 08204.
- Hohman, Betty Jean, 10 Ferris, Apt. 101, Highland Park, MI. 48203 (cones, Volutes, Murices).
- Holiman, Mr. and Mrs. Wayne, Box 246, Edinburgh, TX. 78539.
- Holle, Dr. Paul A., 131 Holman St., Shrewsbury, MA. 01545 (Salt marsh snails).
- Hollister, S.C., 5 Parkway Place, Ithaca, NY. 14850.
- Homan, Mrs. Jacqueline A., Rt. 5, Box 230, Harlingen, TX. 78550.
- Hopkins, Dr. Sewell H., Rt. 3, Box 232, Gloucester, VA. 23061.
- Horan, Robert C., 352 20th St., Brooklyn, NY. 11215 (Biochemistry of shell formation).
- Hornbach, Daniel J., Dept. of Zoology, Miami Univ., Oxford, OH. 45056 (Sphaeriid bivalves).
- Houbnick, Dr. Richard S., Associate Curator of Mollusks, Dept. of Invertebrate Zoology, NMNH, Smithsonian Institution, Washington, DC. 20560 (Zoogeography, systematics, evolution).
- Hubbard, Mrs. Marian S., 3957 Marlow Court, Seaford, NY. 11783 (Littorinidae; all juvenile mollusks).
- Hubricht, Leslie, 4026 35th St., Meridian, MS. 39301 (Land snails and Hydrobiidae of Eastern United States).
- Hucks, Claudia M. 1731 Jervey St., Charleston, S.C. 29407 (Miniature and immature species, East Coast shells).
- Huie, Ms. June, 222 Finland, Grand Prairie, TX. 75050 (All mollusks).
- Hulswit, Mart and Tina, 680 West End Ave., New York, N.Y. 10025 (Scuba).
- Hunkins, Mrs. Ruth E., 133 Brook to Bay, Englewood, FL. 33533 (Miniature shells; exchange).
- Hyett, Dr. and Mrs. Marvin R., 403 Silverhill Rd., Cherry Hill, NJ. 08002.
- Imlay, Dr. Marc J. and Alice, RR3 (K), Box 311, Columbia, MO. 65201.
- Ing, Michael B., Wildwood Sanitarium and Hospital, Wildwood, GA. 30757.
- Ishikawa, Samuel, 551 Fifth Ave., New York, NY. 10017.
- Isom, Billy G., Rt. 2, Box 217, Amy Drive, Killen, AL. 35645.
- Jacobson, Morris K., Oct. to May, 865 Capon St. S.E., M Palm Bay, FL. 32905; June to Oct. 455 Beach 139 St., Rockaway Beach, NY. 11694 (East Coast; land, freshwater and marine; West Indian land shells).
- Jacobson, Mrs. Ursula, 5618 E. Montecito, Phoenix, AZ. 85018 (Indo-Pacific, esp. cones and cowries; West Coast-Panamic).
- Jagger, Mr. and Mrs. James M., RFD #1, Huntington, MA. 01050 (*Tellina*).
- James, Mrs. Frederic, 850 West 42nd St., Kansas City, MO. 64112.
- Jenkinson, John J. and Carolyn, Rt. 3, Box 394, Clinton, TN. 37716.
- Jennwein, Paul R. and Virginia N., Box 394, Wrightsville, Beach, NC. 28480 (Raising mollusks in aquaria; writing and illustrating articles on shell collecting).
- Jensen, Russell H., R.D. #1, Box 55, Chadds Ford, PA. 19317 (Mollusks of Bermuda).
- Joffe, Ms. Anne, 1163 Kittiwake Circle, Sanibel Is., FL. 33957.
- Johns, Veronica Parker, c/o Seashells Unlimited, Inc., 590 Third Ave., New York, NY. 10016.
- Johnson, Col. Harvey A. (Ret.) 3915 S.W. 109th St., Seattle, WA. 98146.
- Johnson, Mrs. Kenneth L., 3206 Sussex Rd., Raleigh, NC. 27607 (World marine).
- Johnson, Richard I., 124 Chestnut Hill Rd., Chestnut Hill, MA. 02167 (Books).
- Johnstone, Mrs. Adelaide B., 226 Wasp, Corpus Christi, TX. 78412.
- Johnstone, Mrs. Kathleen Yerger, 2209 River Forest Rd., Mobile, AL. 36605.
- Jokinen, Eileen, c/o Peter Rich, U-42, Biological Sciences Group, Univ. of Connecticut, Storrs, CT. 06268 (Freshwater gastropods).
- Jones, Margaret C. and Archie L., 4370 S.W. 14 St., Miami, FL. 33134 (*Liguus*).
- Jones, Meredith L., Division of Invert. Zoology, USNM, Smithsonian Institution, Washington, DC. 20560.
- Jones, Richard H., 1432 Dorsh Rd., South Euclid, OH. 44121.
- Jones, Sue, Box 373, Rio Hondo, TX. 78583.
- Josey, Mrs. John S., 222 Devonwood Dr., St. Simons Is., GA. 31522 (Worldwide: self-collected, exchange; Japanese shells and fossils of GA. and FL.; professional artist, marine shells and marine paintings, teaches art at Brunswick Junior College).
- Kat, Pierre W., Dept. Earth and Planetary Sciences, The Johns Hopkins Univ., Baltimore, MD. 21218 (Unionacea).
- Kay, Dr. E. Alison, General Science Dept., Univ. of Hawaii, 2450 Campus Rd., Honolulu, HI. 96822 (Indo-Pacific marine mollusca: systematics and ecology).
- Keegan, Mrs. Barbara, 54 Franklin St., Franklin, NH. 03235.
- Keeler, Dr. James H., 30 Park Lane, Chagrin Falls, OH. 44022 (Marine, esp. micro Gastropods — Epitoniidae and Terebridae).
- Keen, Dr. A. Myra, 2241 Hanover St., Palo Alto, CA. 94306.
- Keferl, Dr. Eugene P., 2610 Oriole St., Brunswick, GA. 31520 (Terrestrial gastropods).
- Kellogg, Michael G., Moss Landing Marine Laboratories, P.O. Box 223, Moss Landing, CA. 95039.
- Kemper, Mrs. Hessie, 11854 Josse Dr., St. Louis, MO. 63128.
- Kennish, Michael J., Madison Ave. at Punch Bowl Rd., Morristown, NJ. 07960 (Shell microstructure in mollusks).
- Kessler, Ms. Catherine G., Three Channing St., Cambridge, MA. 02138 (Unionidae).
- King, Gary and Debra, Official Orders F/2/3, 1916 Berkeley Drive, Azle, TX. 76020.
- King, Lucia E., Heron Club, 434 Broad Ave. South, Naples, FL. 33940.
- Kinsey, Bernard, 350 W. 71st, New York, N.Y. 10023 (Land shells: also worldwide marine shells).
- Kline, Mrs. George F., 240 Makee Rd., Apt. 10-A, Honolulu, HI. 96815.
- Klinkey, Mrs. Martha, 1336 S. 14th St., St. Charles, IL. 60174 (*Cypraea*, *Murex*, *Strombus*).
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- Kondo, Dr. Yoshio, 809 A. Isenberg St., Honolulu, HI. 96826.
- Kotria, M. Bowie, Dept. of Biology, Trinity Univ., 715 Stadium Dr., San Antonio, TX. 78284 (Parasites of snails).
- Kraemer, Dr. Louise Russert and Dr. William D., Dept. of Zoology, Univ. of Arkansas, Fayetteville, AK. 72701 (Freshwater lamellibranchs).
- Kraeuter, Dr. John N., Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Ecology, distribution and systematics of Scaphopoda; benthic infaunal communities of U.S. East Coast).
- Krauss, N.L.H., 2437 Parker Place, Honolulu, HI. 96822 (Carnivorous land snails; biology).
- Krafcheck, James R., 18375 W. Willow Dr., New Berlin, WI. 53151 (Collecting, general).
- Kuczynski, Mrs. Florence, 5562 2nd Ave. N., St. Petersburg, FL. 33710 (Collect, exchange, photograph all shells).
- Kurz, Richard M., 1575 N. 118 St. Wauwatosa, WI. 53226 (Specimen shells).
- Kuzirian, Dr. Alan M., Zool. Dept. Univ. of New Hampshire, Durham, NH. 03824 (Nudibranch biology).
- Laavy, T.L., Rt. 5, Maruca Dr., Greenville, SC. 29609.
- Lalli, Dr. Carol M., Marine Sciences Centre, McGill Univ., 3600 Univ. St., Montreal, Quebec, Canada H3A 2T8 (Pteropod molluscs).
- Lamberts, Dr. Austin, 1520 Leffingwell, N.E., Grand Rapids, MI. 49505 (Coral reefs and associated mollusks).
- Landye, James Jerry, 3465 N. Jamison, Flagstaff, AZ. 86001.
- Lane, Dr. Roger L., Ashabula Campus, Kent State Univ., Ashtabula, OH. 44004 (Morphology, Histology).
- Lange, W. Harry, Dept. of Entomology, Univ. of California Davis, CA. 95616.
- LaRocque, Dr. Aurele, 102 W. Beaumont Rd., Columbus, OH. 43214.
- Laursen, Dr. Dan, 4901 East Eastland, Tucson, AZ. 85711 (Arctic, Subarctic mollusks; Free living larvae of Caribbean and Gulf areas).
- Lee, Dr. Harry G., 709 Lomax St., Jacksonville, FL. 32204 (American mollusks; marine mollusks of the Indian Ocean).
- Lee, Pamela, 2146 Mt. Olympus Dr., Los Angeles, CA. 90046 (Marine).

- Lemire, Ross, 184 Grandview Ave., Thornhill, Ont., Canada L3T 1J1.
- Lerner, Martin, 64 Thompson Ave., Oceanside, NY. 11572 (Worldwide marine).
- Leslie, John, Dept. Biological Sciences, Stanford Univ., Stanford, CA. 94305 (*Haliotis*).
- Lewis, Harold, 138 S. Twentieth St., Philadelphia, PA. 19103.
- Lewis, Mrs. J. Kenneth (Olive), 3340 Windmill Village #185-0, Punta Gorda, FL. 33950.
- Lewis, Dr. and Mrs. John R., 23 W. 551 Warrenville Rd., Lisle, IL. 60532.
- Lewis, Randall B., 210 Chandler Dr., Mundelein, IL. 60060.
- Lewis, Ronald G., 1428 Pennsylvania Ave., Bethlehem, PA. 18018 (Physiology and nomenclature).
- Lillico, Stuart, 4300 Waialae Ave., B-1205, Honolulu, HI. 96816 (General collecting).
- Lindberg, David R., Applied Sciences, Univ. of California, Santa Cruz, CA. 95064.
- Linsley, Dr. Robert M., Dept. of Geology, Colgate Univ., Hamilton, N.Y. 13346 (Paleozoic Gastropoda).
- Lipford, Michael L., 2017 Airline Blvd., Portsmouth, VA. 23701 (Freshwater mussels).
- Littleton, Thomas G., 511 Colonial Parkway, Devine, TX. 78016.
- Logue, Maureen, P.O. Box 3293, Damariscotta, ME. 04543 (Molluscan pathology and aquaculture).
- Long, Dr. Glenn A., 409 Sheridan Circle, Charlestown, W.VA. 25314 (Ethnoconchology).
- Long, Steven J., 792 Laurie Ave., Santa Clara, CA. 95050 (Opisthobranchs, Nudibranchs, Cephalaspideans, Notaspideans, Lamellarians).
- Lopinot, A.C., 45 Northcrest, Litchfield, IL. 62056 (Aquatic biologist, taxonomy and life history of freshwater mussels).
- Lowry, Walter G., 552 Old Lundy Rd., Macon, GA. 31210 (Western Atlantic).
- Lubinsky, Dr. Irene, 32 Thatcher Drive, Winnipeg, Man., Canada R3T 2L2 (Marine bivalves of the Canadian Arctic).
- Lutz, Richard A., Dept. of Geology and Geophysics, Yale Univ., New Haven, CT. 06520 (Bivalve shell structure and mineralogy; molluscan aquaculture; bivalve larval ecology).
- Lyons, Miss Sarah, 81 Lakeview Ave., N.E., Atlanta, GA. 30305.
- Lyons, William G., Florida Dept. of Natural Resources, Marine Lab, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Florida and West Indian mollusks).
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- MacKenzie, Roger Anthony, Lot 12, Morne Coco Rd., Westmoorings, Trinidad, West Indies (Strombidae).
- Mackie, Dr. Gerry L., Dept. of Zoology, Univ. of Guelph, Guelph, Ont. Canada N1G 2W1 (Sphaeriids).
- MacMillan, Gordon K., 169 Glenfield Dr., Pittsburgh, PA. 15235.
- MacMillan, Thomas C., P.O. Belle River, Wood Islands, PEI COA 2JO, Canada.
- Maes, Virginia Orr, Dept. of Mollusks, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103.
- Magee, Mrs. Virginia L., Life Science Dept., Mitchell College, New London, CT. 06382 (New England mollusks, both living and Pleistocene).
- Malek, Dr. Emile, Tulane Univ. Medical School, 1430 Tulane Ave., New Orleans, LA. 70112 (Parasitology).
- Malone, Elsie, 2422 Periwinkle Way, P.O. Box 54, Sanibel Is., FL. 33957 (buy - sell - exchange world shells).
- Mann, Julia, Data Research Associates, 257 Park Ave. South, New York, N.Y. 10010.
- Marshall, Dr. Donald S., Far Lands House, 3414 Halcyon Dr., Alexandria, VA. 22305.
- Marshall, Elsie J. (Mrs. Thomas H.), 2237 N.E. 175th St., Seattle, WA. 98155 (World shells; exch.).
- Marti, Mrs. Ann, P.O. Box 7, Trinity, AL. 35673.
- Martins, Antonio M., Frias, Dept. of Zoology, Univ. of Rhode Island, Kingston, RI. 02881.
- Mastenbroek, Paul W., P.O. Box 67, Woodbridge, Ontario L4L 1A9, Canada (Distribution and systematics, Northern North Atlantic Ocean and adjacent seas).
- Mather, Dr. Charles M., Ass't. Prof. of Biology, Box 3457, University of Science and Arts of Oklahoma, Chickasha, OK. 73018 (Systematics and ecology of terrestrial molluscs and freshwater mussels).
- Mathiak, Harold A. and Julie, 209 S. Finch St., Horicon, WI. 53032 (Natural history of Wisconsin clams and recent species distribution; effects of fish toxicants on clams).
- May, Miss L. Helen, 8110 Ketcham Rd., South, Bloomington, IND. 47401 (N.A. seashells, emphasis on continental U.S.A.).
- Mayers, Dan, 648 Wiltshire Dr., State College, PA. 16801 (Studies done on mollusks, classification).
- Mayo, Beryl Ivy and Franklin, 319 Narcissus Rd., Rt. 1, Kemah, TX. 77565 (Gulf shallow water and drift mollusks).
- Mazurkiewicz, Dr. Michael, Dept. of Biological Sciences, Univ. of Southern Maine, 96 Falmouth St., Portland, ME. 04103 (Larval development and ecology of estuarine mollusks).
- McBeth, Lewis Dean, 3401 Patio Drive, Erie, PA. 16506 (Collector of worldwide mollusks).
- McCaleb, John E., 782 Worth Blvd., C-41, Pottstown, PA. 19464 (Freshwater mollusks of N.A., esp. Pleuroceridae).
- McCallum, John and Gladys, 4960 Gulf of Mexico Dr., Apt. PH6, Longboat Key, FL. 33548.
- McCarty, Col. William A., 424 Hunting Lodge Dr., Miami Springs, FL. 33166.
- McCrary, Dr. Anne B., 411 Summer Rest Rd., Wilmington, NC. 28403.
- McGee, Paul L. and Helen, 10211 Bessemer, Houston, TX. 77034.
- McGinty, Thomas L., Box 765, Boynton Beach, FL. 33435.
- McHugh, Mrs. John, 4654 Quarry Ridge, Rockford, IL. 61103 (*Murex*).
- McInnes, Mrs. Cornelia G., F-6 Raleigh Apts., Raleigh, NC. 27605 (All Marine).
- McLean, Dr. James H., Los Angeles County Museum, 900 Exposition Blvd., Los Angeles, CA. 90007.
- McLeod, Dr. Michael J., Biology Dept., Belmont Abbey College, Belmont, NC. 28012 (Systematics and evolution).
- McRae, Mrs. Catherine, 1984 Roseate Lane, Sanibel Is., FL. 33957.
- Menzel, Dr. R.W., Dept. of Oceanography, Florida State Univ., Tallahassee, FL. 32306 (Oysters; clams).
- Merrill, Arthur and Harriet, 133 Coco Plum Drive, Marathon, FL. 33050.
- Metcalf, Dr. Artie L., Dept. of Biological Sciences, Univ. of Texas at El Paso, El Paso, TX. 79968 (Terrestrial Gastropoda of S.W. U.S.).
- Metz, George, 121 Wild Horse Valley Drive, Novato, CA. 94947 (Chitons).
- Meyer, Harvey G. and Maude W., P.O. Box 61, Captiva, FL. 33924.
- Michaelson, Eliot, The Shell Gallery, Piccadilly Sq., 77 Union St., Newton Centre, MA. 02159.
- Michelson, Dr. Edward H., 15 Edmonds Rd., Apt. 189, Framingham, MA. 01701 (Medical malacology).
- Mikkelsen, Paul and Paula, 508B S. 22nd St., Ft. Pierce, FL. 33450 (Donacidae - Paul; Tellinidae and Littorinidae - Paula).
- Miles, Dr. Charles D., 5100 Rockhill Rd., Biological Sciences Bldg., Kansas City, MO. 64110.
- Miller, Barry B., Dept. of Geology, Kent State Univ., Kent, OH. 44242 (Non-marine Pleistocene, Malacology).
- Miller, Dr. Walter B., 6140 Cerrada El Ocote, Tucson, AZ. 85718.
- Miser, Wendel L., 1108 Alden Rd., Alexandria, VA. 22308 (Fresh water mollusks).
- Moller, Gertrude H., Mrs. 2248 University Blvd. South, Jacksonville, FL. 32216.
- Moore, Dr. and Mrs. Donald R., Rosensteel School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Moore, Eric and Eileen, P.O. Box 6606, Orange, CA. 92667.
- Morrison, Dr. J.P.E., 1330 4th St. S.W., Washington, DC. 20024.
- Morrison, Robert W., P.O. Box 15011, Sarasota, FL. 33579 (Marine shells, esp. *Cypraea*, *Voluta*, *Oliva* and *Murex*).
- Mousley, Louis B., 35350 Panorama Dr, Yucaipa, CA. 92399.
- Murray, Mrs. Francis A., 3741 N.E. 24th Ave., Lighthouse Point, FL. 33064.
- Murray, Dr. Harold D., Biology Dept., Trinity Univ., San Antonio, TX. 78284 (Unionidae; distribution and parasites).

- Murray, Talbot, Graduate Sch. of Oceanography, Univ. of Rhode Island, Narragansett, RI. 02882.
- Myer, Dr. Donal G., Dept. of Biological Science, Southern Illinois Univ. at Edwardsville, IL. 62025 (Land snails).
- Naide, Dr. Meyer, 2034 Spruce St., Philadelphia, PA. 19103.
- Neck, Dr. Raymond W., Texas Parks and Wildlife Dept., 4200 Smith School Rd., Austin, TX. 78744 (Ecology, evolution and biogeography of nonmarine Mollusca).
- Nelson, Jack and Linda, 116 Rawlings Rd., Gaithersburg, MD. 20760 (*Murex*, *Mitre*, *Cymatium*).
- Neville, Bruce D., Hancock Foundation, Univ. of Southern California, Los Angeles, CA. 90007 (Mangrove mollusks, systematics and ecology).
- Nicol, Dr. David, P.O. Box 14376, University Station, Gainesville, FL. 32604.
- Nicolaci, Mr. and Mrs. Domenick, Bella Vista ls., Box 147, Fairhaven, MA. 02719 (*Pecten*; exchange).
- Nilson, Joy S., RFD #1, Box 233, E. Wareham, MA. 02538 (All mollusks of New England area).
- Noseworthy, Ronald G., P.O. Box 104, 41 Main St., Grand Bank, Newfoundland, Canada AOE 1W0 (North Am. circumboreal mollusks; also Clausiliidae and Turridae).
- Notter, Miss Helen, 1115 S. Edgewood Ave., Apt. 608, Jacksonville, FL. 32205.
- Nunnally, Sally and Doug, 512 North Channel Dr., Apt. B, Wrightsville Beach, NC. 28480.
- Nybakk, Dr. James, Moss Landing Marine Laboratories, Box 223, Moss Landing, CA. 95039.
- Oatis, Bona D., 312 Holiday Park Dr., Pittsburgh, PA. 15239 (World marines; exchange).
- Ode, Dr. Helmer, 4811 Braeburn Dr., Bellaire, TX. 77401 (Gulf of Mexico marines).
- Oesch, D. Ronald, 9 Hill Dr., Glendale, MO. 63122 (Missouri mussel zoogeography).
- Oetzell, Miss Edith M., 518 S. Ardmore Ave., Villa Park, IL. 60181 (*Conus*).
- Old, William E. Jr., Dept. of Mollusks, American Museum of Natural History, Central Park W. at 79th St., New York, NY. 10024.
- Oliveira, Dr. Maury Pinto de, Dept. Biologia-Malacologia, Universidade Federal, De Juiz De Fora, Cidade Universitaria, 36100 Juiz de Fora, Minas Gerais, Brazil.
- Olsen, Philip L., 10708 Blossom Lane, Silver Spring, MD. 20903 (Cape Hatteras to Cape Cod mollusks).
- Oppenheimer, Dr. Ella H., 7703 Crossland Rd., Baltimore, MD. 21208.
- Orchard, C.D., P.O. Box 115, McQueeney, TX. 78123.
- Ostheimer, Alfred J., III, 1030 Mansion Ridge Road, Santa Fe, N.M. 87501.
- Pace, Dr. Gary L., Univ. of Michigan, Biology Dept., Flint, MI. 48503.
- Palmer, Dr. Katherine V.W., 206 Oak Hill Rd., Ithaca, NY. 14850.
- Parker, James Larry, 8705 Valleybrook Rd., Birmingham, AL. 35206 (Tropical marine gastropods).
- Parker, Mr. and Mrs. Robert S., 256 Doucet Rd., Lafayette, LA. 70503.
- Parmalee, Dr. Paul W., Prof. of Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916 (Freshwater mollusks from archaeological sites).
- Parodiz, Juan Jose and Esther, 409 Ruthwood Ave., Pittsburgh, PA. 15227 (Neotropical mollusks and fresh water gastropods of U.S.A.).
- Patch, Diana Craig, 4522 Springfield Ave., Apt. 2F, Philadelphia, PA. 19143 (Grad student in Anthropology, U. of Penn.).
- Penchaszadeh, Dr. Pablo E., Dept. Estudios Ambientales, Universidad Simon Bolivar, Caracas, Venezuela, Apartado Postal 80.659.
- Petit, Mr. and Mrs. Richard, P.O. Box 30, North Myrtle Beach, SC. 29582 (World shells).
- Petuch, Ed, Rosenstil School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Conidae).
- Peyton, Gary, 1107 Panhandle, Denton, TX. 76201 (Environmental chemistry, interested in effect of chemical pollutants on mollusks).
- Phillips, Ted, General Delivery, Riviera, AZ. 86442.
- Pierce, Dr. Harold G., Rt. 2, Box 67B, Lexington, VA. 24450.
- Pipher, Phyllis and Bernard T., 1116 N. St., Tekamah, NE 68061 (Collectors especially of cones, *Murex*, volutes).
- Piplani, Shirley A., 26 Jameson Place, West Caldwell, NJ. 07006 (Chitons).
- Porter, Hugh J., UNC Inst. Marine Sciences, Morehead City, NC. 28557 (Systematics, culture of bivalves).
- Post, Mrs. Alfred P. Jr., P.O. Box 65, Darlington, MD. 21034.
- Powell, Dr. Eric N., Dept. of Oceanography, Texas A&M University, College Station, TX. 77843 (Pyramidellidae; benthic ecology).
- Pratt, W.L. Jr. and Suzann Denton Pratt, Museum of Natural History, Univ. of Nevada, Las Vegas, 4505 Maryland Pkwy. S., Las Vegas, NV. 89154.
- Prezant, Robert S., College of Marine Studies, Univ. of Delaware, Lewes, DE. 19958 (Anomalodesmata; mantle structure and function/evolution).
- Pulley, Dr. Thomas E., Director, Houston Museum of Natural Science, P.O. Box 8175, Houston, TX. 77004.
- Quinn, James F., Jr., RSMAS BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Trochidae and Turridae).
- Raeihle, Dorothy and George, 211 Milligan Rd., West Babylon, NY. 11704.
- Raup, Timothy A., 910 Farrell Ave., Kalamazoo, MI. 49007 (*Conus*).
- Ray, Diana J., 542 Ledge Road, Seekonk, MA. 02771.
- Raymond, Torrance, C., 99 Ridgeview Rd., Poughkeepsie, NY. 12603.
- Reader, Mr. and Mrs. William R., 4772 49th Ave. North, St. Petersburg, FL. 33714 (Live mollusks).
- Reeder, Dr. Richard L., Faculty of Nat. Sci. Univ. of Tulsa, Tulsa, OK. 74104 (Land pulmonates).
- Reehm, Ms. Avon A., Box 3421, Galveston, TX. 77552.
- Rehder, Dr. Harald A., 5620 Ogden Rd., Washington, DC. 20016.
- Rice, Thomas C., Of Sea and Shore Publications, P.O. Box 33, Port Gamble, WA. 98364.
- Richards, Charles S., Lab. of Parasitic Diseases, National Institute of Health, Bethesda, MD. 20014 (Freshwater mollusks, host-parasite relations, mollusk pathology and genetics).
- Riggle, Stan, 26 E. Market St., Iowa City, IO. 52240.
- Rios, Dr. Eliezer de C., Box 379, Museo Oceanografico, Rio Grande, RS. 96200, Brazil.
- Ritchie, Mrs. Robert M., 17 Country Club Pl., Bloomington, IL. 61701.
- Roach, Frank and Joan D., 1028 Belvoir Rd., Norristown, PA. 19401 (Specializing in *Cardium*, *Chama* and *Pecten*).
- Roberts, Mr. and Mrs. H. Wallace, Hopkinson House, Apt. 2816, Washington Square South, Philadelphia, PA. 19106 (Marine).
- Robertson, Dr. Robert, Dept. of Malacology, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (Marine).
- Root, John, P.O. Box 182, West Palm Beach, FL. 33402.
- Roper, Dr. Clyde F.E. and Ingrid, Dept. of Invertebrate Zoology, USNM - Smithsonian, Washington, DC. 20560 (Systematics and ecology of the Cephalopoda).
- Ropes, John W., P.O. Box 56, Pattee Rd., Teaticket, MA. 02536.
- Rosewater, Dr. and Mrs. Joseph, Dept. of Invertebrate Zoology (mollusks), USNM of Natural History, Washington, DC. 20560.
- Roth, Barry, Dept. of Geology, Calif. Academy of Sciences, San Francisco, CA. 94118.
- Rotter, Dr. Saul D., 170 North Ocean Blvd., Palm Beach, FL. 33480 (Cones, Volutes, Cowries, Olives).
- Roworth, Edwin C., 1361 Windsor Rd., Cardiff-by-the-Sea, CA. 92007 (World shells and sea life).
- Runnels, Randy J., Rt. 2, Box 518, Brazoria, TX. 77422 (Gulf of Mexico mollusks, especially gastropods).
- Russell, Charles E., 10602 Jordan Rd., Carmel, IN. 46032 (land; freshwater shells).
- Russell, Dr. Henry D., 50 Springdale Ave., Dover, MA. 02030.
- Russell, Dr. Lois S. Royal Ontario Museum, 100 Queen's Park, Toronto, Ont., Canada M5S 2C6.
- Russell-Hunter, Dr. W.D., Dept. of Biology, 112 Lyman Hall, Syracuse Univ., Syracuse, NY. 13210.
- Rutter, Kurt L., P.O. Box 107, Stanton, NJ. 08885 (Shells of the littoral area).
- Sage, Walter E. III, 1123 Hathaway, Louisville, KY. 40215.

- Sartor, James C., 5606 Duxbury, Houston, TX. 77035 (Microscopic marine mollusks — exchange or purchase).
- Scarabino, Sr. Victor, Instituto de Investigaciones Biologicas, Avda. Italia 3318, Montevideo, Uruguay.
- Schell, Frederic B. Jr., 1200 Peppertree Lane, Apt. 102, Sarasota, FL. 33581 (winter); The Brooklands, Colebrook, CT. 06021 (June 1-Nov. 1).
- Scheuerman, Clara, 1366 Twinsburg Rd., Macedonia, OH. 44056 (*Harpa*, *Cypraea*, helmets).
- Schilling, Mr. and Mrs. Albert E., 419 Linden Ave., Glenside, PA. 19038 (Mr. *Cypraea*; Mrs. *Murex*; both, *Conus*).
- Schilling, Mrs. Frieda, 3707 Lan Dr., St. Louis, MO. 63125.
- Schriner, Miriam W. and Howard Jr., Rt. #2, Box 127, LaBelle, FL. 33935 (Paleo-malacological research).
- Schuyler, Clint, 229 East Allen St., Lancaster, OH. 43130 (Collecting and studying shells).
- Seip, William F., 1555 Stonewood Rd., Baltimore, MD. 21239.
- Serrill, Linda and Richard, P.O. Box 207, Matagorda, TX. 77457 (Shells of the Matagorda, TX. area).
- Shasky, Donald R., M.D., 834 Highland Ave., Redlands, CA. 92373.
- Shaw, William N., 209 Sycamore Ave., Easton, MD. 21601 (Shellfish culture).
- Shimek, Dr. Ronald, Dept. of Biological Sciences, Univ. of Alaska, 3221 Providence Dr., Anchorage, AK. 99504 (Turrid gastropods, gastropod systematics, subtidal benthic marine ecology).
- Shoemaker, Alan H., 330 Shereditch Rd., Columbia, SC. 29210 (littoral and shallow sublittoral mollusks).
- Sibley, Frederick D., 196 Christopher St., Montclair, NJ. 07042.
- Sickel, Dr. James B., Biol. Dept. Murray State Univ., Murray, KY. 42071 (Unionidae ecology and physiology).
- Siddall, Scott E., School of Marine Sci. BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Physiological ecology of bivalves, particularly marine mussels and mariculture of mussels).
- Siekman, Mrs. Lula B., 5031 41st St., St. Petersburg, FL. 33711.
- Simpson, Herbert, Shell dealer and collecting guide in the Florida Keys, Rt. 2, Box 14-A, Sugarloaf Key, FL. 33044 (*Spondylus americanus*, Florida Keys and Caribbean shells).
- Skinner, Drew V. Jr., P.O. Box 208, Bremerton, WA. 98310.
- Skoglund, Carol, 3846 E. Highland Ave., Phoenix, AZ. 85018 (Panamic Province shells).
- Smith, Douglas G., Dept. of Zoology, Morrill Science Center, Univ. of Mass., Amherst, MA. 01003 (Land and freshwater mollusca of NE North America).
- Smith, Ellen C., 16 Cromeset Rd., Wareham, MA. 02571.
- Smith, Dr. Francis A., 1023 55th Ave. South, St. Petersburg, FL. 33705 (Microscopic marine mollusks of Florida).
- Smith, Mrs. Hattie Little, P.O. Box 1053, Foley, AL. 36535 (Gulf of Mexico).
- Smith, Dr. Judith Terry, 1527 Byron St., Palo Alto, CA. 94301.
- Smith, Lawrence C., 51 Coppertree Lane, Babylon, NY. 11702.
- Smith, R.V. and Mrs. Muriel F.I. National Museum of Natural Sciences (Malacology), Ottawa, Ont., Canada K1A 0M8.
- Smrchek, Dr. Jerry C., 3316 King William Dr., Olney, MD. 20832 (Effects of pollution on freshwater mollusca).
- Snyder, Martin Avery, 745 Newton Rd., Villanova, PA. 19085.
- Sohl, Dr. Norman F., 10629 Marbury Rd., Oakton, VA. 22124.
- Solem, Dr. Alan, Dept. of Zoology, Field Museum of Nat. History, Chicago, IL. 60605.
- Sparks, Mrs. Mary K., 6493 60th Ave., N.W., Oak Harbor, WA. 98277 (*Cypraea*, *Murex*, ecology of marine habitats; exchange).
- Sparks, Richard E., Illinois Natural History Survey, Havana, IL. 62644.
- Sphon, Gale G. Jr., Los Angeles County Museum, Invertebrate Zoology, 900 Exposition Blvd., Los Angeles, CA. 90007.
- Stanzione, Mrs. Antonetta R., 55 Green Ave., Barrington, R.I. 02806 (Studying shell life in the balance of nature).
- Stainken, Dennis, 51 Coughlan Ave., Staten Island, NY. 10310 (Anatomy and physiology of bivalves, effects of marine pollutants).
- Stansbery, Dr. David H., Museum of Zoology, Ohio State Univ., 1813 North High St., Columbus, OH. 43210 (Naiads).
- Steger, Mrs. Dan, 2711 68th St. N., Tampa, FL. 33619 (Marine fauna of Gulf of Mexico).
- Stein, Dr. Carol B., Museum of Zoology, Ohio State Univ., 1813 North High St., Columbus, OH. 43210 (Naiads, Gastropoda).
- Stelzig, Theresa (Mrs. O. Cline), 109 Duke Lane, Portland, TX. 78374.
- Starnes, Lynn B. and Wayne C., TVA Forestry Bldg., Norris, TN. 37828 (Zoogeography of southeastern U.S. mollusks).
- Stern, Dr. Edward M., Dept. of Biology, Univ. of Wisconsin-Stevens Point, Stevens Point, WI. 54481 (Systematics and ecology of terrestrial gastropods and Unionidae).
- St. John, Dr. Mary Ellen and Dr. F. Lee, 155 Van Tassell Ave., Newark, OH. 43055 (Naiads, esp. *Actinonais ligamentina*).
- Steward, Supt. Orville M., P.O. Box 450, Briarcliff Manor, NY. 10510.
- Stingley, Dale V., P.O. Box 113, LaBelle, FL. 33935.
- Strenth, Dr. Ned E., Dept. of Biology, Angelo State Univ., San Angelo, TX. 76901 (General ecology, systematics, and larval development of opisthobranch molluscs of the Genus *Aplysia*).
- Strieder, Dr. Denise J., 143 Laurel Rd., Chestnut Hill, MA. 02167 (American shells).
- Sullivan, Joseph E., Bureau of Economic Geology, Univ. of Texas, University Station, Box X, Austin, TX. 78712.
- Sutow, Dr. Wataru W., 4371 North MacGregor Way, Houston, TX. 77004 (*Strombus*; exchange).
- Sypek, Joseph P., Marine Pathology Laboratory, Univ. of Rhode Is., Kingston, Rhode Island 02881; home add: 16 Edmund St. Chicopee Falls, MA. 01020 (Histopathology and parasitology of marine pelecypods particularly *Mytilus* and *Mya*).
- Talmadge, Robert R., 2850 Pine St., Eureka, CA. 95501 (Haliotidae; benthic invertebrates).
- Tate, Mrs. Mildred, 211 Huisache, Lake Jackson, TX. 77566.
- Taylor, Dr. Dwight W., Tiburon Center for Environmental Studies, P.O. Box 773, Tiburon, CA. 94920.
- Taylor, Myra L., 7602 McCulloch Ave., San Antonio, TX. 78216 (Shells of the Texas coast).
- Taylor, Dr. Ralph W., Dept. of Biological Science, Marshall University, Huntington, W.VA. 25701 (Mussels of W.VA. and KY., land snails of W.VA.).
- Taxon, Mr. and Mrs. Albert, 1300 NE 191st St., Apt. 211, North Miami Beach, FL. 33179.
- Teskey, Mrs. Margaret C., P.O. Box 273, Big Pine Key, FL. 33043.
- Thomas, Georgia and Jim, RD #2 Linvale Rd., Box 214, Ringoes, NJ. 08551 (Worldwide specimens emphasis on *Cypraea*, *Murex*, Volutes, Cones; also interest in the migration and feeding habits of mollusks).
- Thomas, Dr. Grace, Dept. of Zoology, Univ. of Georgia, Athens, GA. 30602 (Sphaeriids).
- Thomas, Miss Marguerite T., P.O. Box 721, Swansboro, NC 28584.
- Thompson, Dr. Fred G., Florida State Museum, Gainesville, FL. 32601 (Land and freshwater mollusks; systematics).
- Thorpe, Fran Hutchings, 3910 Battersea Rd., Coconut Grove, FL. 33133.
- Tippett, Dr. and Mrs. Donn L., 10281 Gainsborough Rd., Potomac, MD. 20854 (Western Atlantic, living and fossil — Cones, *Murex*, scallops, Fissurellidae).
- Toll, Ronald B., Rosenstiel School of Marine and Atmospheric Science — BLR, 4600 Rickenbacker Causeway, Virginia Key, FL. 33149 (Systematics of Cephalopods).
- Tompa, Dr. Alex S., Museum of Zoology, Univ. of Michigan, Ann Arbor, MI. 48109 (Land and freshwater mollusks).
- Treece, D. Granvil, University of Texas Marine Science Institute, Port Aransas, TX. 78373 (Molluscan systematics; taxonomy; zoogeography).
- Trinidad, Dr. Victor Jose V., 22040 Westhampton, Oak Park, MI. 48237 (Cowries, cones, olives and Tibias).
- Tunnell, Dr. John W. Jr., Corpus Christi State Univ., Corpus Christi, TX. 78411 (Systematics, distribution and ecology of reef and bank molluscs of Gulf of Mexico).
- Turgeon, Dr. Donna D. and Dr. Kenneth W., Marine Science Consortium, Box 16, Wallops Island, VA. 23337 (Marine bivalves (planktonic to adult) systematics and ecology).
- Turner, Dr. Ruth D., Museum of Comparative Zoology, Harvard Univ.,

- Cambridge, MA. 02138.
- Underwood, Harold T., Dept. of Biology, Texas A&M University, College Station, TX. 77843 (Interested in molluscs as they serve in the capacity as hosts in parasite life cycles).
- Vagvolgyi, Dr. Joseph, Biology Dept., College of Staten Island, B-204, 715 Ocean Terrace, Staten Island, NY. 10301 (Evolutionary theory; zoogeography).
- Vail, Dr. Virginia, Tall Timbers Research Station, Rt. 1, Box 160, Tallahassee, FL. 32303.
- Van der Schalie, Dr. Henry, 15000 Buss Rd., Manchester, MI. 48158.
- Van Devender, R. Wayne and Amy S., Rt. 4, Box 261-B, Boone, N.C. 28607 (Land snails).
- Vecchione, Michael, Virginia Institute of Marine Science, Gloucester Point, VA. 23062 (Ecology and systematics of pelagic molluscs).
- Vega, Dr. Luis Eduardo, 420 S. Essex Ln., Tucson, AZ. 85711.
- Vidrine, Malcolm F., 306 Thomas St., Lafayette, LA. 70506 (Fresh water mussels of Louisiana; study of water mites).
- Villarroel, Dr. Maria M., Instituto de Ingenieria, Dept. Ing. Ambiental, APDO 70-472, Mexico 20, DF, Mexico.
- Vokes, Dr. Harold E. and Dr. Emily H., Dept. of Geology, Tulane Univ., New Orleans, LA. 70118 (Mesozoic and Tertiary mollusks; fossil and recent Muricidae).
- Voss, Dr. Gilbert L., Prof. of Biological Oceanography, Div. of Biology and Living Resources, RSMAS, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Wagner, Robert J.L., R.D. 1, Box 21, Marathon, FL. 33050 (Purchase shells).
- Walker, R. Lindsay Jr., Apartado 06 Postal 344, San Salvador, El Salvador, Central America.
- Walklet, Gerrie, Randolph Farms, #1401, 13300 Indian Rocks Rd., Largo, FL. 33540.
- Waller, Dr. Thomas R., Dept. of Paleobiology, Smithsonian, Washington, DC. 20560 (Zoogeography, ecology, evolution of Cenozoic Pectinidae).
- Walter, Dr. Waldemar, Dept. of Biological Sci., Western Illinois Univ., Macomb, IL. 61455.
- Warmke, Germaine L., 1711 S.W. 43rd Ave., Gainesville, FL. 32607 (Mollusks of the Caribbean).
- Warren, Dr. Sol L., 375 Garden Blvd., Garden City, NY. 11530.
- Wasili, Mrs. John (Odessa), P.O. Box 187, Frisco, NC. 27936.
- Waters, Ruth A., 150 Barker Hill Dr., RFD 3, Guilford, CT. 06437 (U.S. marine, principally E. Coast).
- Way, Carl Michael, Dept. of Zoology, Miami University, Oxford, OH. 45056 (Ecology and physiology of the Sphaeriidae and freshwater gastropods).
- Wayne, Dr. William J., M.H. 412, Dept. of Geology, Univ. of Nebraska, Lincoln, NB. 68588 (Pleistocene non-marine mollusks).
- Webb, Dr. Glenn R., Rt. 1, Box 1158, Fleetwood, PA. 19522.
- Webb, John A. and Rhoda, 27132 Butternut Ridge Rd., North Olmsted, OH. 44070.
- Weingartner, Mathilde P., 17 Amelia Court, Staten Island, NY. 10310.
- Weisbord, Norman E. and Nettie S., Dept. of Geology, Florida State Univ., Tallahassee, FL. 32306 (Cenozoic and recent).
- Weiss, Harold M., 3607 Sarah Dr., Watauga, NY. 11793 (Conidae and Cypraeidae).
- Weity, Stephen L., Box 639, Dubois, WY. 82513.
- Werner, Milton, 70 Richmond St., Brooklyn, NY. 11208.
- West, Dr. Ronald R. and L.E. (Lois) Gundrum, Dept. of Geology, Kansas State Univ., Manhattan, KS. 66506.
- Westcott, Russell T., 24 Duke Dr., Stamford, CT. 06905 (general study of marine mollusks).
- Westerfield, Mrs. A.C., Apt. C203, 429 Montgomery Ave., Haverford, PA. 19041 (Marine shells).
- Wheel, Mr. and Mrs. Adlai B. Sr., 4501 West Seneca Turnpike, Syracuse, NY. 13215.
- White, Kenneth J., R.Ph., 2587 Ballew Ct., Marietta, GA. 30062 (Caribbean Province shells).
- Whiteside, Mrs. Smith (Jeanne), Rt. 3, Box 902-G, Merritt Island, FL. 32952.
- Whitsett, Mrs. J.M., 4214 W. 70th St., Prairie Village, KS. 66208.
- Wightman, Dr. Eugene P., 85 Harding Rd., Rochester, NY. 14612 (World marine).
- Wilie, William L. Jr., 1405 McFaddin, Beaumont, TX. 77701 (*Conus*).
- Williams, Frances (Fran), 438 N.W. 7th St., Miami, FL. 33126.
- Williams, Dr. James D., 2318 Hiladrose Dr., Silver Spring, MD. 20902 (Freshwater mussels; zoogeography and systematics).
- Williams, Mrs. Margaret A., Rt. 3, Box 28A, Sarasota, FL. 33580 (Caribbean and miniature).
- Williamson, Catherine, 4026 Willow Dr., Corpus Christi, TX. 78411 (Natural history — ecology).
- Willis, Jeffrey A., 402 Kings Highway, Lewes, DE. 19958.
- Wilson, Mrs. Bill T., P.O. Box 191, Ingleside, TX. 78362 (Strombidae; amateur collector).
- Wilson, Dr. Druid, Room 501, U.S. National Museum, Washington, DC. 20560.
- Windnagel, John, 3581 Snouffer Rd., Worthington, OH. 43085 (Florida shells).
- Winger, Dr. Parley V., U.S. Fish and Wildlife Service, CNFRL — Field Research — Athens; School Forest Resources; Univ. of Georgia, Athens, GA. 30602.
- Withrow, Mr. and Mrs. Carl C., 6720 35th Terr. N., St. Petersburg, FL. 33710.
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The Forty-Sixth Annual Meeting of the American Malacological Union will be held in Louisville, Kentucky, the week of July 19-24, 1980. Headquarters will be at the Executive Motor Inn. The Louisville Conchological Society will act as host organization. Symposia on feeding mechanisms of mollusks and functional morphology of Cephalopods are planned. There will be a book auction. Direct inquiries to AMU President Dr. Clyde F.E. Roper, Dept. of Invertebrate Zoology, USNM, Smithsonian, Washington, D.C. 20560.

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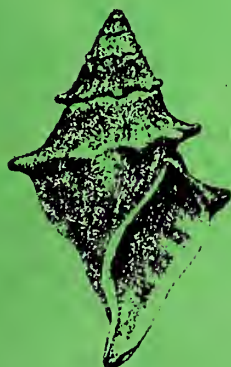
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for 1980

**COVERING THE
FORTY SIXTH
ANNUAL MEETING**

**July 19-25, 1980
Louisville, Kentucky**



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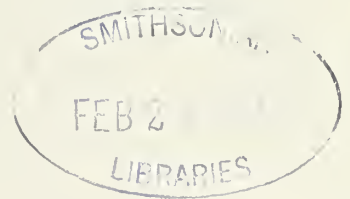
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Errata: Please make the following changes in your 1980 Bulletin.

Page 70

- 1) Line 3 from top - *granifers* should be *granifera*."
- 2) Line 12 from top - "so that little gland tissue was seen in same" should read "so that little gland tissue was seen in some."
- 3) Line 16 from bottom - *Philop thalmus* should read *Philophthalmus*.



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THE AMERICAN MALACOLOGICAL UNION, INC.

FORTY-SIXTH ANNUAL MEETING

JULY 19-25, 1980
LOUISVILLE, KENTUCKY

Attractions of Louisville, Ky., came out third best in the three-ring circus of the 46th Annual Meeting of the American Malacological Union in that city's Executive Inn East.

Not that the city of museums, steamboats, German cooking, colonels, tobacco and whisky didn't try. The 26-person sponsoring organization had prepared a busy schedule, Saturday through Friday.

The first contingent of the 157 persons who registered were treated to refreshments and samples of hot and cold culinary delights from the kitchens of the Louisville Conchological Society during the President's Reception Saturday evening. Of significant appeal were the Kentucky-famed beaten biscuits with country ham, large mushroom caps served with a dip and a huge variety of cheeses.

Registration resumed Sunday. "Goody bags" provided a wealth of handy items, maps and sightseeing directions. Along with registration were, first, the meeting of the Conservation Committee, and then the meeting of the Council of Systematic Malacology (a group of curators and museum directors interested in malacology). Dr. Fred G. Thompson of Florida State Museum, Gainesville, Fla., was elected chairperson of that council. Mrs. Smith Whiteside of Merritt Island, Fla., chairman of the Conservation Committee, was unable to attend and tendered her resignation as chairperson. It was accepted and she was later warmly praised for her past efforts in relation to conservation.

President Clyde F.E. Roper called to order the opening session of the 46th Annual Meeting at 1 p.m. Sunday. He termed preparations for the meeting by the Louisville Conchological Society a "magnificent job" He said membership in the AMU was the "last remaining bargain in the country". He outlined what those attending might expect and explained the significance of the ribbons on name tags. In addition to the blue and red ones, designating local committee and officers, respectively, green ribbons were used for the first time. These designated affiliated shell club representatives (who had received a reduction in their registration fee to encourage representation from a key group in the scientific organization). Roper also praised Walter E. Sage III who served as liaison person in making arrangements for the host club.

In the absence of Mayor William B. Stansbury of Louisville (reportedly out of town but presumably seeking relief from the near 100-degree temperatures), Dr. David H. Stansbery filled in. He was introduced as the "mayor of malacology." He cited history of the area, indicating famous malacologists who worked and died in the area. He said the area was among the most productive for bivalves.

President Tony Horak of the host club issued a welcome and thanked the members for their help and support.

Roper presented the ground rules for presentation of papers. Ten papers had been planned by students for the student competition but only eight were entered. The \$100 prize winner's name was announced at the banquet after judging by a secret committee. At the close of the opening session, numbers were drawn that corresponded with those placed on name tags. Mrs. Mary Rosewater won the first door prize, a bottle of corn-squeezings for which Kentucky is famous.

Presentation of papers followed the opening session. Most unusual was that of Donald R. Moore, School of Marine Science, Miami, Fla., with his first venture in the field of freshwater molluscs. The paper told of the hoax perpetrated by James J. Audubon on C.S. Rafinesque, French botanist and naturalist who described freshwater molluscs over 100 years ago. He taught near the Falls of the Ohio. Audubon reportedly had been upset to find Rafinesque nude in his attic, chasing bats with Audubon's best violin. Audubon suggested there was a limpet with a trap-door at its apex, from

which the mollusc's head would emerge when disturbed. Rafinesque duly reported the specimen, although he'd never seen it. A drawing in the Rafinesque papers is the only sample.

Buses arrived on time Sunday evening for transportation to the Ohio River, but drivers disappeared soon after their arrival. A search for them was finally initiated as frantic telephoning developed between the hosts and the school and boat officials. The 800-passenger *Belle of Louisville*, last remaining steamboat on the Ohio River, had been chartered by the host club and waited until the last 30 passengers arrived. Two kegs of beer were tapped as the boat moved away from the dock (beverage laws in the South are peculiar and those were topped off with a buffet supper which made the trip very enjoyable. Providing peasant and court dances was a troupe of Philippine dancers, led by LCS President Horak and his wife Delsie. It was a tired group which returned, some well after midnight, to the Executive Inn near the airport.

Decisions had to be made Monday. Contributed papers and a symposium on "Functional Morphology in Cephalopods" provided a choice. Sightseeing in Louisville also presented a choice, except most had been instructed to return for the group picture. The day's cephalopod symposium prompted one observer to say he'd heard more than he ever wanted to know about bait.

That evening, slide presentations were made by Gene Everson of Plantation, Fla., on "Deep-water Shells from the Philippines;" Dorothy Beetle of Columbus, Ga., on "Reflections of Past AMU Meetings," and by James E. Conklin of the University of Louisville on "An Introduction to the Falls of the Ohio."

Tuesday's papers included cephalopods, so that those who had missed Monday's symposium had an opportunity to learn about other aspects of malacology and cephalopod participants could take in papers on gastropods and pelecypods. However, choices still remained between hearing papers and attending workshops on "Freshwater Mollusks" in the morning and "Terrestrial Mollusks" in the afternoon. Dr. Stansbery led the one on freshwater fauna; Dr. Thompson, that on land snails.

In the evening, Roger Hanlon and Raymond Hixon, both of the Marine Biomedical Institute, Galveston, Texas, showed slides of the underwater aspects of the Red Sea, with background music composed and played on the piano by Hanlon's mother with a recorded narration. The presentation was fully professional. A book, reprint and print auction, led by Dr. R. Tucker Abbott of Melbourne, Fla., with William E. Old Jr. of New York as auctioneer, raised \$1,700. A Texas Party with Kentucky products followed on the sixth floor and lasted well into Wednesday morning.

Wednesday's activities started with a shopping tour of Louisville for some of the wives and others who'd had enough of mollusks for awhile. A workshop on underwater photography, led by Hanlon and Hixon, competed with more papers. That afternoon, the AMU Council met for lunch. The meeting lasted almost until supper. Twenty-one members attended. Actions were later ratified by the membership at the next day's business session.

Wednesday night's popular presentations consisted of two workshops: on "Marine Aquaria," headed by Michael J. Sweeney of the National Museum of Natural History, Washington, D.C.; and the other on "Marine Molluscs," led by Dr. Abbott. The latter featured an outline of what publications should be available for those trying to identify specimens.

A Symposium on "Feeding Mechanisms of Predatory Mollusks" was led Thursday by Dr. Alan J. Kohn of the Department of Zoology,

University of Washington, Seattle. With a break for lunch, it lasted until the start of the annual business session.

News of the death of past president Morris Karl Jacobson the previous Monday saddened those attending the banquet. The banquet speaker was William J. Conklin, chief radiologic technologist, Orangeburg Regional Hospital, Orangeburg, S.C. Conklin showed slides of shells, followed by X-Ray pictures of how they appear. He also showed several bizarre X-Ray photographs from hospital files around the country.

William M. Kier of the Department of Zoology, Duke University, Durham, N.C., whose paper on the muscle structure of squid arms and tentacles included a film in slow motion on actual seizing of prey, was awarded the \$100 prize for the best paper. Judges remained anonymous.

Three field trips completed activities of the meeting Friday. Eugene Kerfel led a group to Sleepy Hollow, a gorge on the South Fork of Harrod's Creek, 2½ miles north of U.S. 71, where terrestrial snails, freshwater bivalves and fossils of the Ordovician and Silurian periods were found. Dr. Stansbery took a group to Floyd's Fork for freshwater fauna. James E. Conklin led a group to the Falls of the Ohio to collect fossils.

Those chairing sessions during the week included Harold D. Murray, Eugene Kerfel, Virginia Vail, William Hulet, Gilbert L. Voss, Roger T. Hanlon, Joseph Rosewater and Virginia Maes.

Paul Jennewein
Corresponding Secretary

MORRIS KARL JACOBSON

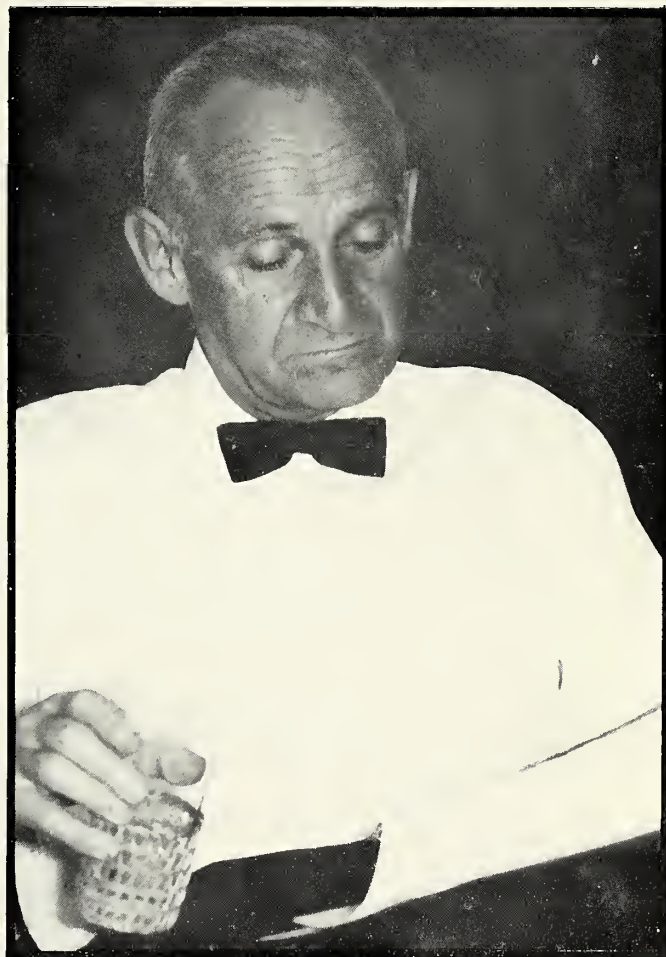
1906 - 1980

The death of Karl Jacobson on July 21, 1980 at Melbourne, Florida came as a shock to his many friends and colleagues. Karl and his wife Lena ('Pinky') had recently moved permanently to Palm Bay, Florida, where they had spent the past three winters away from their longtime home in Rockaway Beach, New York. Karl was born December 29, 1906 in Memel, East Prussia (now Klaipeda, Lithuania) and emigrated to the United States with his family, first settling in New Jersey, in 1907. He was formally trained in linguistics (B.S., New York University, 1928; M.A., Columbia University, 1930), and was a highly respected teacher of foreign languages in the New York City School system for more than thirty years. He retired from active teaching in 1968 after serving the last 15 years of his career as the chairman of the Department of Foreign Languages of Andrew Jackson High School in Queens, New York.

A frustrated student of natural history, Karl became interested in mollusks when he and Pinky moved to Rockaway Beach in 1937, where he had an opportunity to explore the adjacent shores of Long Island. He was a co-founder of the New York Shell Club and served as the first president of the Club (1949-1952) and editor of the Club Notes (1949-1959). He joined the American Malacological Union in 1940 and was president in 1954-1955, presiding at the 22nd annual meeting at Staten Island, New York in July, 1955. At the 1980 AMU meeting, Karl was voted an Honorary Life Member, but sadly he did not live to know of this recognition.

Karl collected exhaustively everywhere in the New York City area and undertook collecting trips to Cuba, Mexico, Jamaica, Puerto Rico, Central America, and the Lesser Antilles. As a result of these excursions, and by exchanging with collectors from all parts of the world, Karl assembled a large and well-documented reference collection of mollusks, which formed the basis for many of his scientific publications, totaling more than 70 titles. Several of his titles were contributions to a monographic study of the Cuban land snails of the family Helicinidae written in collaboration with Drs. William J. Clench and Kenneth J. Boss of Harvard University (1968-1975). His papers reflected a broad interest in malacology and dealt with marine and fresh-water mollusks, as well as with terrestrial gastropods. Two species of mollusks, *Rhytidothyra jacobsoni* Alcalde, 1949, and *Streptostyla jacobsoni* Pilsbry, 1951, were named in his honor.

Shortly after I joined the staff of the American Museum of Natural History, Karl asked me to co-author with him the handbook, "Shells of the New York City Area" (1961), which was based largely on his local collecting experience. In all, he co-authored eight popular books, ranging in scope from the semi-technical "American Museum of Natural History Guide to Shells, Land, Freshwater, and Marine, from Nova Scotia to Florida," to six titles in the prestigious juvenile readership, "Wonders" series of Dodd, Mead (1971 to 1980), dealing with such diverse inverte-



MORRIS KARL JACOBSON
1906 - 1980

brate groups as mollusks, sponges, corals, starfish, and jellyfish. Additionally, Karl contributed numerous articles and book reviews to the New York Shell Club "Notes" and other publications.

Karl was a strong supporter of the malacological program of the American Museum of Natural History, where he held the honorary title of Associate in Malacology, commencing in 1964. His contributions in-

cluded the gifts of his valuable shell collection (marine in 1969; land and freshwater in 1972) and of his extensive collection of reprints of articles on mollusks, in 1977. He also made generous donations to the Malacology Research Fund of the Museum.

Karl Jacobson's many scholarly achievements, especially in the fields of linguistics, teaching, science, and writing, are legacies to the intellectual betterment of mankind. His many friends will fondly remember him, however, for his seemingly endless energy in the pursuit of knowledge and for the invigorating contagiousness of his zest for life.

William K. Emerson
American Museum of Natural History

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September 19, 1980

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Wonders of Snails and Slugs. Dodd, Mead & Co., 96 pp., 1980 (and David R. Franz).

POPULAR WRITINGS AND BOOK REVIEWS

Numerous articles and book reviews in New York Shell Club "Notes" and other journals.



CONTRIBUTED PAPERS PRESENTED AT THE 1980 MEETING

FIFTY YEARS OF MALACOLOGY
AT THE UNIVERSITY OF MICHIGAN (1929-1979)

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ABSTRACT

Studies of mollusks undertaken in the Mollusk Division during the half century period were supervised by Calvin Goodrich from 1929-1944; by Henry van der Schalie from 1944 to 1977; and by John B. Burch and Alex Tompa from 1977 to the present time. Scholarly precedents set by Bryant Walker served as a basis for the Division work. Four theses were completed during the Goodrich period; about 36 afterward. Support for more doctoral students was made possible through grants and contracts and by structuring the work along *interdisciplinary* lines. Three main units developed: one devoted to systematics and the building of collections, another concerned with cytogenetics in a new part of the Museums Building, and a third used for studies in medical malacology. The chief granting agencies were: the Commission on Parasitic Diseases (Armed Forces Epidemiological Board) to study roles of snails as intermediate hosts in parasitic diseases; a training grant from the National Institutes of Health to support graduate student work; a gift from the Rockefeller Foundation to tide the Division over tight-money periods; and a grant from the Environmental Protection Agency to determine the effects of ambient temperature on the growth and reproduction of aquatic snails.

Some of the more important additions to the collections were the following: the Max Ellis mussel assemblage from the Mississippi and lower Tennessee rivers; lots contributed by Clarence Clark from Ohio and Michigan; the collections from the Royal Ontario Museum of Zoology curated largely by the Reverend Harry Herington; two large collections donated by Captain Robert E. Kuntz of the Navy and obtained from the New Hebrides and from Taiwan; interglacial mollusks contributed by the late Dr. Claude W. Hibbard and curated by Drs. Dwight Taylor, Barry Miller and others; and many mussel tissues collected and prepared by John M. Bates from the Muskingum River in eastern Ohio, as well as from many other drainages.

For almost a century mollusk studies have been undertaken at the University's Museum of Zoology sponsored largely in a scholastic way by its Zoology Department (now Division of Biological Sciences). The initial and sustained influence of Bryant Walker, a great civic leader and lawyer in the early 1900's, cannot be emphasized enough. In addition to maintaining a museum and a private collection of mollusks in a building at the rear of his Detroit residence, he encouraged such persons as H.B. Baker, William J. Clench, Mina Winslow, Calvin Goodrich and others in their mollusk interests. Their work on campus was in the "old Museum" building which later became the Romance Language building. The new Museum building (Alexander G. Ruthven Museums) was completed in 1928 and housed six divisions - one of which became the present Mollusk unit. Both Bryant Walker and Arnold E. Ortmann (then at the Carnegie Museum in Pittsburgh) encouraged Calvin Goodrich to concentrate his studies on pleurocerid snails. In 1926 Goodrich retired from newspaper work to become a full-time Assistant Curator under Miss Mina Winslow, then Curator of Mollusks in the old Museum. When she took a leave of absence in 1929, Goodrich served as Curator and Henry van der Schalie became his graduate student assistant. The next fifteen years could be called the "Goodrich Period" in mollusk studies, ending with his retirement in 1944.

THE GOODRICH PERIOD (1929-1944)

During the time of his curatorship the Division made considerable progress. Field excursions were undertaken in Michigan and in several of the southern states. The accomplishments for that period were given in an article by the writer with the title: "Calvin Goodrich - 1874 - 1954" (*Nautilus*, 68:135-142). Until restrictions brought about by the war limited travel, many expeditions were made to productive limestone regions in the south. To encourage studies of mollusks in Michigan, Goodrich published a handbook, "The Mollusca of Michigan." (Michigan Handbook Series, No. 5, University of Michigan Press, 1932). He also brought an industrious and methodical approach to the Division work. Through field collecting, accessing and cataloguing the collections grew to about 50,000 lots*. In 1929, Dr. Bryant Walker had a stroke; he died in 1936. His collections and library were willed to the Mollusk Division in Ann Arbor. There were 100,000 lots housed in 40 museum cases; six cataloguers worked for two years to access these remarkably rich land and freshwater collections - perhaps the best of its kind in the United States.

During this period the following students completed their doctorate studies in the Mollusk Division:

Henry van der Schalie wrote a thesis, completed in 1934, on the ecology and distribution of the mussels in the Huron River drainage. These data clearly revealed the relation of patterns in distribution to former stream confluences as naiades were transferred in post-glacial periods across drainage divides by fish. The studies were later extended to other drainages of the glaciated regions. Mussel ecology proved an important key to the distribution patterns established. Additional studies are now needed in greater detail to assist the disciplines concerned with mussel transfers to save endangered species now disappearing in streams altered by modern "development" schemes.

Alan F. Archer came from the Museum of Comparative Zoology at Harvard with a strong interest in land snails. His thesis, completed in 1936, concentrated on the Stenotremes (Polygyridae). He also provided useful lists of land snails in Cheboygan County, the region of the University of Michigan Biological Station, and in the Edwin George Reserve near Pinckney, Michigan. The latter has been used in studies monitoring return of the biota to natural conditions after years of agricultural use.

Elmer G. Berry completed his thesis in 1937 with a study of the Amnicolidae of Michigan, a large family with species in the many lakes and streams of this state. His work on their anatomy, radular structure, ecology and distribution, as well as the systematics of that group, remains a major contribution.

Dr. Phil L. Marsh, a medical doctor with amateur mollusk interests, was most helpful in cataloguing the land snail collections from the Walker holdings. For a time he lived in Jackson, commuted to Ann Arbor, and provided much expertise in the Walker accession work. Gaps revealed in the distribution of land snails were later filled during special trips he made throughout Michigan (and elsewhere).

The Bryant Walker collections and library remain as a monument to one of the most outstanding scholars in malacology. His extensive studies on land and freshwater mollusks of North America and his purchases of some of the best of the early collections, made when the fauna was not greatly altered by environmental changes, provided information perhaps never again available. Walker worked in collaboration with the active institutions of his time. The field studies were made in southern states by a professional collector, Herbert Huntington Smith, supported by a "Syn-

*A lot is a species from one locality; the number of specimens is immaterial.

dicade" consisting of H.A. Pilsbry, George Clapp, John B. Henderson and Truman Aldrich. Over a twenty-year period Smith made extensive collections in drainages flowing to the Gulf of Mexico. The collections were shared by the museums represented by the members of the Syndicate.

THE VAN DER SCHALIE PERIOD (1944-1977)

After Goodrich's retirement in 1944, Henry van der Schalie was appointed Curator of Mollusks, continuing in this capacity until his retirement in 1977. The World War II constraints on work other than war effort left little opportunity for field work and travel. The Mollusk Division was fortunate to be given a special dispensation that furnished funds for field studies of *Pomatiopsis* snails thought to be potential hosts for *Schistosoma japonicum* (Oriental schistosomiasis) entering the United States when infected soldiers and trained dogs returned from battle areas. Field surveys were undertaken in collaboration with the parasitological laboratories of Horace Stunkard in New York University and George R. LaRue at Michigan. Elmer Berry had left to work in the Tropical Diseases Laboratory of the National Institutes of Health in Washington, D.C. He did manage, with great effort, to infect *Pomatiopsis lapidaria* with *S. japonicum*. It was such a difficult task and the health hazards seemed so remote that the field studies were not continued.

At the time of Goodrich's retirement an Assistant Curatorship was open to Aurele LaRocque. He had worked in the National Museum of Canada for about fifteen years and had just completed the requirements for his bachelor's degree at the University of Ottawa. In the three-year period he spent at Michigan he not only did an outstanding job in curatorial work but he also completed his studies toward a doctorate in paleontology. In his spare time he also organized the second index to the *Nautilus*. That useful work was later prepared for publication with the assistance of Geneva Smythe (Museums secretary) and Harold W. Harry who succeeded LaRocque in Division curatorial work. The Index volume was dedicated to Bryant Walker.

When World War II ended, funds for travel and research became available and investigators in schools were encouraged to apply for them through grants and contracts. Research budgets in schools greatly increased and offices for research administration were established. The interdisciplinary prospects for work with mollusks enabled the Division to grow from a unit with one curator and an assistant to a program involving as many as thirty personnel. The involvements gave impetus to studies in several disciplines; malacologists in the Division shared investigations with faculty in several departments of the Literature, Science and Arts College and in other schools of the University as well. While emphasis continued on the basic studies related to the systematics, ecology and distribution of mollusks, investigations were encouraged in several related fields including physiography, geomorphology and paleoecology, anthropology and ethnoconchology, public health, natural resources and, more recently, environmental law.

The Museum of Zoology is an integral part of the teaching program sponsored by the Zoology Department. Students earning degrees must have a reasonably wide course distribution. With the rapid growth in fields related to mollusks, the demand for training in multidisciplinary studies is increasing far beyond the ability of most schools to meet those requirements. As indicated in the list (appended) of the approximately 36 theses undertaken with Mollusk Division sponsorship, the work not only involved staff in the Literature, Science and Arts College, but concerned such schools as Public Health, Natural Resources, Pharmacology and others.

Only a few of the sponsors for mollusk work can be mentioned, but the agencies with broad interests and those supporting studies in the Division were as follows:

1. Commission on Parasitic Diseases: Armed Forces Epidemiological

Board. This program was in force for a twenty-year period starting after the completion of the World Health Organization Project (Egypt 10) in the vicinity of Cairo by the writer during 1952-53 and again in 1954. The Division was supported in a series of studies under the general heading: "American *Pomatiopsis* snails having many biological similarities to the Oriental *Oncomelania*, the intermediate hosts of Oriental schistosomiasis." The investigators in the Commission were recruited from a dozen American universities and they were encouraged with government support to study human blood flukes (schistosomiasis or bilharziasis). Yearly summary reports for the work done in the Mollusk Division at Michigan were prepared as well as two final technical reports, the first for the period 1955-1964, the second for 1965-1972. The studies on the distribution and ecology of *Pomatiopsis* and its Oriental counterparts, including five strains of *Oncomelania*, can be grouped into the following categories:

- (1) *Field* - The egg-laying, movements, nature of soils on which those snails live, their algal foods, temperature and humidity in their habitats, etc., were studied and reported for *Pomatiopsis lapidaria* and *P. cincinnatiensis*. Since in many ways the field conditions for both *Pomatiopsis* and *Oncomelania* are the same, these studies on *Pomatiopsis* serve for those projected involving *Oncomelania*.
- (2) *Laboratory* - Two laboratory manuals were published setting forth the methods developed for maintaining these amphibious snails in laboratory culture.
- (3) *Anatomy and Morphology* - Several papers carefully delineate the comparative anatomical relations of *Pomatiopsis*, *Oncomelania* and related Oriental groups. Anomalies among snails in the orient were shown.
- (4) *Culture Methods* - Study of life histories of the two species of *Pomatiopsis* enabled the development of techniques for culturing the *Oncomelania* that serve as intermediate host snails. Five subspecies of *Oncomelania hupensis* (*hupensis*, *nosophora*, *formosana*, *quadrasi* and *chiui*) were routinely maintained in culture and used for studies with strains of *Schistosoma japonicum* in medical and public health work. Studies on the effect of crowding on the pulmonate snails, *Biomphalaria pfeifferi* and *Bulinus globosus*, were done, as well as research on the influence of calcium and magnesium salts on their growth and reproduction. A new snail host, *Lithoglyphopsis aperta*, was brought from the Mekong and established in culture.
- (5) *Snail-Host Relations* - Many of the snails maintained in the laboratory were challenged with a wide variety of human and non-human of schistosomes. Selective processes produced a steady increase in snail susceptibility. Infectivity was found related to the age of the snails exposed, the number of miracidia used, and optimum temperatures.
- (6) *Cytogenetics* - The studies of Burch, Patterson (Morgan), Lindsay, Wu and others greatly advanced knowledge of snail chromosomes. The cytogenetics laboratory has grown and has been supplied with proper equipment; the work has flourished under the sponsorships of Burch, Lindsay, Davis and others. Dr. Vera King Farris completed some impressive studies of snail tissue culture. Electrophoresis and immunoelectrophoresis studies were initiated in the Mollusk Division and the work is continuing both at Michigan under Burch and at the Philadelphia Academy under Davis.

Principal Professional Assistants supported by the Commission on Parasitic Diseases for the Period 1955-1973 were:

*Dee Saunders Dundee	(1955-1956)
*Harold J. Walter	(1955-1956)
Yuri Otori	(1956-1957)

*Paul F. Basch	(1958-1959)
Lowell L. Getz	(1959-1962)
*George M. Davis	(1962-1965)
John B. Burch	(1963-1968)
*Gary Pace	(1965-1968)
*Charlotte Patterson	
(Morgan)	(1965-1966; 1972-1973)
Gene K. Lindsay	(1965-1969)
*Chin-tsong Lo	(1966-1969)
*Yung-san Liang	(1966-1972)
Vera Collaro	(1968-1972)
John French	(1969-1972)
Marilyn Parker	(1970-1972)

*Those whose work contributed toward their Ph.D. degree

II. *Training Grant Sponsored by the National Institutes of Health (1959-1974)* Much of the graduate student work in the Division was supported by the N.I.H. training grant that extended over a fifteen-year period. By combining the equipment and facilities acquired through the support to this agency with that obtained with the support of the Armed Forces, the work of the Division was developed far more in depth than otherwise possible. During the Goodrich period there was only one compound microscope in the whole of the Museum program; it was in the Mollusk Division. With the assistance of the grants, contracts and the expertise of some excellent and well-trained personnel, John B. "Jack" Burch, aided by Gene Lindsay (a chemist), Charlotte Patterson Morgan, and George M. Davis and others built a well-equipped laboratory in which many important cytogenetic studies were undertaken involving a wide variety of mollusk groups. Several visiting investigators such as Dr. R. Natarajan from India, Dr. Catalina Quadros, Dr. Donald Wootton and Dr. Vera King Farnis, worked in that center. The list of publications produced by Dr. Burch and his co-workers is impressive and it is largely to his credit that this excellent and highly productive cytogenetic laboratory was developed as a part of the Mollusk Division program. *Malacologia* and *Malacological Review* - two journals were initiated by Dr. Burch and with the able initial assistance of Julie Huber, Charlotte Patterson Morgan, and Anne Giomanni, these journals are now among the best in the field of malacology.

III. *National Institutes of Health; Geographic Medicine Branch (1967-1977)* On the strength of the success shown in the cultures, (see "Culture Methods" section) the Geographic Medicine Branch of the National Institutes of Health awarded funds over this ten-year period to the Medical malacology unit of the Mollusk Division to provide researchers at other institutions with schistosome-infected animals (snails, mice, hamsters, dogs). Toward the end of the period about 75 laboratories were receiving snails and rodents infected with the three human schistosomes: *Schistosoma mansoni*, *S. haematobium* and *S. japonicum*. The cycles maintained included all of those known for *S. japonicum* (including the strain from mainland China brought from Dr. Hans Vogel's laboratory in Hamburg, Germany, by van der Schalie); six strains of *S. haematobium* from as many countries; and six strains of *S. mansoni* from six different countries. This center for supply not only gave some excellent possibilities for snail studies but was a boost to many U.S. research programs in chemotherapy, serology, host-parasite relations and immunology when these materials became available at a minimal cost. The cycle work was carried on mainly by three principal investigators - Drs. Henry van der Schalie, Elmer G. Berry and Harvey Blankespoor.

Both Yung-san Liang and Chin-Tsong Lo, students from Taiwan, completed their thesis work with studies involving snail culture and their expertise was most helpful in the maintenance of the many cycles used in the medical zoology studies. Their work as published is cited in the theses here reported.

This program involving the maintenance and supply of schistosome cycles was greatly enhanced by work contributed by Harvey Blankespoor who joined the Division in 1971. He was soon recruited by the Zoology Department to teach Parasitology. His research has tended more toward snail-related problems involving swimmer's itch (schistosome dermatitis) - a widespread and serious problem in the Great Lakes region.

With the excellent assistance provided by the staff in the units of the Division it was hoped that it might be possible to establish a Medical Malacology Institute. While the value of such an institute was generally recognized, appeals to foundations and granting agencies proved fruitless. The medical malacology program was transferred in 1977 to the University of Lowell, Massachusetts, with some of the key personnel. Cultures are no longer maintained at Michigan.

IV. *Rockefeller Foundation Gift to Mollusk Division (1971-1974)* When funds were difficult to obtain, the Rockefeller Foundation generously provided a substantial gift to be used for a three-year period to tide the Division through tight money situations. The funds were most helpful in supporting key people, bringing Dr. Blankespoor to the program and building aquarium room facilities both for the laboratory at 912 Main Street and later for the aquarium and infection rooms built on the top floor of the West Medical Building - now known as the C.C. Little Science Building. Some of the studies undertaken with this support involved several non-human schistosomes and their snail hosts carrying swimmer's itch (schistosome dermatitis).

V. *Environmental Protection Agency (EPA-R3-73-021) (1969-1972)* Results of a three-year study on the effects of temperature on growth and reproduction of aquatic snails, sponsored by E.P.A., was published as a report by Henry van der Schalie and Elmer G. Berry (cited above); it also appeared through the generous assistance of Aurele LaRocque in *Sterkiana* (50: 1-92, 58 figures, 20 tables, 11 plates, 7 maps). The effects of temperature on the biology of freshwater snails were studied using two lymnaeids (*Lymnaea stagnalis* and *L. catascopium* = *emarginata*), three planorbids (*Helisoma trivolvis*, *H. anceps* and *H. campanulatum*) and one physid (*Physa gyrina*) - all pulmonate or "pond" snails; only one gill-breathing operculate (*Amnicola limosa*) was tested in the several temperatures ranging from 6°C to 36°C. These researches led van der Schalie and Blankespoor to recommend that a pilot project be undertaken in a focal situation in a human schistosome endemic area. The results of that study were published in an article entitled: "Potential Use of Solar Energy for Snail-Host Control" (*The Biologist*, 59: 16-21, 1977).

Whatever success the Mollusk Division has had in managing the above grants and contracts is attributed to the many who have given support in the work. The three main secretaries who served more as administrative assistants deserve special commendation for their continued and loyal services. In the order of their association in the Division, they are: Mrs. Elizabeth Huber, Mrs. Margie Mayer and, more recently, Mrs. Evelyn Peer. The staff's services in managing budgets was of a high order of competence and their efforts gave more time for the curators and the assistants who were relieved of some of the financial details.

HIGHLIGHTS OF THE MOLLUSK COLLECTIONS

Freshwater mussels or naiades have been among the intensely studied groups starting with the excellent Walker collections. During the heyday of the mussel industry when the U.S. Bureau of Fisheries was conducting widespread mussel surveys, the identifications were usually made by Bryant Walker. Even the monumental Simpson Catalog on mussels was not only published by Walker but he took an active part in its preparation. More recently Goodrich, Clench, van der Schalie and others made surveys of drainage systems many of which have long since been

changed by pollution or modern "developments." Several of the larger accessions should be mentioned:

(1) In addition to his work as Professor of Physiology at the University of Missouri, Dr. Max M. Ellis was for several years in charge of the inland rivers survey for the U.S. Bureau of Fisheries. Early in the 1930's he and members of his staff made an extensive survey of the mussels in the Mississippi River from St. Anthony Falls in Minnesota to St. Louis; they also collected in the Tennessee River from the region of Muscle Shoals to its mouth near Paducah, Kentucky. The Ellis collections remain a landmark for all seeking knowledge of the mussels in those rivers.

(2) Clarence Clark was for many years associated with fisheries work in Ohio. He collected land snails from several counties in Ohio and made surveys of rivers to learn the ecology and distribution of the mussels. His collections were generously deposited in the Mollusk Division and some

of them have recently been used in publications dealing with tributaries of the Maumee River in Ohio and Michigan.

(3) The Reverend Harry Herrington was a collaborator in the Division for many years. His work with the Sphaeriids was started with the encouragement of Dr. John Oughton in the Royal Ontario Museum at Toronto. Herrington's "Revision of the Sphaeriidae of North America" was completed with the assistance of the staff at Michigan. He corresponded with A.E. Stelfox in England. When Stelfox retired, his collections were donated to Herrington who was sent with Mollusk Division sponsorship to Dublin to bring the Stelfox collection to Michigan. Herrington curated and accessed it. Later he was able to work as an assistant in the U.M. Mollusk Division to access and incorporate the collections of the Royal Ontario Museum. A working collection was returned to the Ontario museum; the bulk of the Oughton and other

Theses Sponsored by the U. M. Mollusk Division (1929-1979)

Goodrich period (1929-1944)

Date	Author	Thesis Title	Committee Chairman
1934	van der Schalie, Henry	The Naïad fauna of the Huron River in Southeastern Michigan	C. L. Hubbs
1936	Archer, Alan F.	A study of the Stenotreme Polygyrae	L. R. Dice
1937	Berry, Elmer G.	The Amnicolidae of Michigan	L. R. Dice
1941	Whitney, Esther M.	The hermaphrodite gland and germ cells of <i>Valtonia pulchella</i> Mull.	P. Okkelberg
1946	Matteson, Max R.	Life history and ecology of <i>Elliptio complanatus</i> (Billwyn)	F. E. Eggleton

van der Schalie period (1944-1979)

1951	Lee, Charles B.	The Molluscan family Succineidae in Michigan: considerations of anatomy, early embryology and distribution	H. van der Schalie
1951	Harry, Harold W.	<i>Carychium exiguum</i> of Lower Michigan	H. van der Schalie
1952	Abdel-Malek, Emile	Host-parasite relations of Planorbidae	H. van der Schalie
1953	Clench, William J.	Origin of the land and freshwater mollusk fauna of the Bahamas, with a list of the species occurring on Cat and Little San Salvador Islands	P. Okkelberg
1953	DeWitt, Robert M.	Studies of the biology of <i>Physa gyrina</i> Say; ecology and life history	F. E. Eggleton
1954	Mitchell, Roger D.	Anatomy, life history, and evolution of the sites parasitizing fresh water mussels	H. van der Schalie
1955	Thomas, Grace J.	Some Aspects of the Biology of <i>Sphaerium</i> (Musculium) <i>partumcum</i>	F. E. Eggleton
1956	McCraw, Bruce M.	Studies of the anatomy, ecology and growth of <i>Lymnaea humilis</i> Say	H. van der Schalie
1956	Dundee, Dee S.	Aspects of the biology of <i>Pomatopsis lapidaria</i> Say	H. van der Schalie
1956	Solem, Alan R.	A systematic and zoogeographic survey of the non-marine mollusks of the New Hebrides	H. van der Schalie
1958	Basch, Paul F.	The morphology and biology of <i>Ferrissia fusca</i> (Adams): a comparative study	H. van der Schalie
1959	Burch, John B.	Chromosomes of aquatic pulmonate snails	H. van der Schalie
1960	Walter, Harold J.	The morphology of <i>Stagnicola emarginata serrata</i> (Haldeman) and its relation to lymnaeid systematics	H. van der Schalie
1962	Heard, William H.	Some comparative life histories of pill clams (Sphaeriidae: <i>Pisidium</i>)	H. van der Schalie
1962	Dazo, Bonifacio C.	The morphology and natural history of <i>Pleurocera acuta</i> Taf. and <i>Goniobasis livescens</i> (Henke)	H. van der Schalie
1964	Goudsmit, Esther M.	The metabolism of galactogen and glycogen by the pulmonate snails <i>Lymnaea megasoma</i> and <i>Helix pomatia</i>	H. van der Schalie
1965	Davis, George M.	The systematic relationship of <i>Pomatopsis lapidaria</i> (Say)	H. van der Schalie

and *Oncomelania hupensis formosana* (Pilsbry and Hirase)

1966	Kraemer, Louise R.	The mantle flap in three species of freshwater mussels, <i>Lampsilis</i>	H. van der Schalie
1968	Wall, Robert C.	An analysis of the current status of the Schistosoma dermatitis problem in Michigan	W. B. Stapp
1968	Lo, Chin-Tsong	Compatibility and host-parasite relationship between <i>Bulinus</i> Müller and an Egyptian strain of <i>Schistosoma haematobium</i> (Bilharz)	E. G. Berry
1969	Hallon, Elizabeth J.	Some factors to success in fields at the University of Michigan	B. E. Voss
1970	Upatham, Edward S.	Studies on the ecology of the miracidium of <i>Schistosoma mansoni</i> Sambon in relation to its snail intermediate host, <i>Biomphalaria glabrata</i> (Say) in a static water habitat	A. B. Cowan
1970	Morgan, Charlotte M. Patterson	Taxonomic studies of the land snail family Succineidae	J. B. Burch
1971	Wu, Shi-Kuei	Comparative studies on a polyploid series in the African snail genus <i>Bulinus</i>	J. B. Burch
1971	Lloyd, Margaret C.	The biology of <i>Searlesia dira</i> (Mollusca: Gastropoda) with emphasis on feeding	H. van der Schalie
1971	Chen, Chun-fan	Pacemaker properties of completely isolated neurons in the gastropod <i>Aplysia californica</i>	J. Bardach
1971	LoVerde, Philip T.	Studies on the avian schistosoma <i>Gigantobilharzia huronensis</i> , with reference to sex-determination	A. B. Cowan
1972	Tsai, Chang Swei	Synthesis of some antimalarials	J. Burckhalter
1972	Pace, Gary	The freshwater mollusks of Taiwan	H. van der Schalie
1973	Liang, Yung-san	Cultivation of <i>Bulinus</i> (<i>Physopsis</i>) <i>globosus</i> (Morelet) and <i>Biomphalaria pfeifferi</i> (<i>pfeifferi</i>) (Krauss), snail hosts of schistosomiasis	R. J. Porter
1974	French, John R. P.	Improved methods for culturing the subspecies of <i>Oncomelania hupensis</i> ; the snail hosts of <i>Schistosoma japonicum</i> , the Oriental human blood fluke	F. K. Lagler
1974	Klemm, Donald J.	Studies on the feeding relationships of leeches (Annelida: Hirudinea) as natural associates on mollusks	A. B. Cowan
1975	McDonald, Sharon L. C.	Behavior of the snail <i>Lymnaea stagnalis</i> (L.) in relation to temperature	F. Mooper
1976	LoVerde, Philip T.	Host-parasite interrelationships between the trematode <i>Schistosoma haematobium</i> from Egypt and polyploid snails of the genus <i>Bulinus</i>	R. J. Porter
1976	Rudolph, Paul H.	Aspects of the reproductive biology of <i>Stagnicola elodes</i> (Say); the histochemistry and maturation of reproductive systems, and copulation	J. B. Burch
1978	Greene, Lyford K.	<i>Gigantobilharzia huronensis</i> : development in <i>Physa gyrina</i> and histochemistry of the daughter sporocyst and developing cercariae	J. B. Burch
1978	Te, George A.	A systematic study of the family Physidae	J. B. Burch

collections housed there are now in the Mollusk Division at Michigan.

(4) Retired Naval Captain Robert E. Kuntz donated two large collections. One was from the area of New Hebrides on which collection Alan Solem wrote his doctoral thesis. The other large collection was from Taiwan where, with the assistance of Chin-tsong Lo, Dr. Kuntz made field collections for a period of over five years. John Burch and the writer later spent three months in Taiwan rounding out the Kuntz collections; those collections were the basis for a thesis by Gary Pace.

(5) The late Dr. Claude W. Hibbard worked in the Museum of Paleontology at Michigan for many years during which he conducted field surveys in interglacial fossil deposits. Because of the collaborative efforts of Dwight Taylor, Barry Miller and others, the Mollusk Division now has a large and valuable collection of the mollusks from the interglacial beds. Their value is enhanced in that they are carefully and properly zoned as to the horizon and knowledge of the ecology and distribution of the many mollusk groups represented permits a projection of conditions that existed during those geologic times. The Hibbard collection of mollusks is among the best available.

(6) Especially noteworthy among the more recent mussel collections are the many well-relaxed and carefully preserved mussels gathered in a three-year survey of the Muskingum River in eastern Ohio by John M. Bates, a former student at the University of Michigan, and, at the time, a faculty member at Eastern Michigan University. Other survey members included Sally Dennis, Robert Wakefield, William Kovalak and the writer. Their reports (unfortunately not published) submitted to the State of Ohio authorities covered: (1) ecology and distribution of the 36 species of mussels in that river; (2) an algal study to relate productivity of food to mussel abundance; and (3) physical-chemical data on water quality in

that stream. The large supply of animal tissues obtained there made possible a study in which one hundred mussel species were sectioned; all but three were dioecious or sexes separate. Additional tissue collections have been likewise prepared from several other large drainage systems.

An apology is due those whose work and efforts may have been inadvertently omitted. The Mollusk Division has had a great deal of support both from the University and from private benefactors, including William G. Fargo who established a trust fund used to support projects for which other funds were unavailable. The facilities which the University has provided to house some 250,000 lots of mollusks for use in biological and related studies are among the best in the country. It is a serious problem today for those who work along interdisciplinary lines to get scholastic and other assistance outside an immediate department within a school. Mollusk students at Michigan have earned degrees in several schools and departments other than the L.S. and A. College. In the long run, the staff and investigators are not hurt as much as the students who should be profiting more from expertise available in other schools on the campus. The list of theses (perhaps not as complete as it should be) is testimony to the broad scope that mollusk work attains. Hopefully in the future more schools can develop programs that will be essentially interdisciplinary.

With the writer's retirement in 1977, the work of the Division is being continued by Drs. John B. Burch and Alex Tompa. It is with great hope that the next half century in this unit will be as enjoyable and promising as the last.

The extensive work of students and colleagues, many of whom could not be included in the descriptive outline given above, is shown chronologically in the list of theses herein.

ON THE NEWLY DISCOVERED RELATIONSHIP BETWEEN THE PARASITIC GASTROPOD *BALCIS CATALINENSIS* AND ITS HOLOTHURIAN HOST *BRANDTOTHURIA ARENICOLA*

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ABSTRACT

The parasitic gastropod, *Balcis catalinensis*, throughout the Bay of La Paz, Mexico, is commonly found on exterior surfaces of and in the stomach of, the holothurian *Brandtothuria arenicola*. This is the first report of *B. catalinensis* as a parasite and the first parasite ever reported in association with *B. arenicola*. The number of parasites found in the stomach of the host is positively correlated with the length of *Brandtothuria* as well as its population density. The percentage of infected hosts is also correlated with host density. Neither the percentage of infected hosts nor the number of parasites in or on the host is affected by the depth at which *Brandtothuria* is collected. *Balcis* has a short survival time when apart from the host averaging two days and experiments indicate the *B. catalinensis* randomly encounters its host. There is no correlation between survival time and size of the parasite, indicating that juveniles and adults are both highly dependent on the host. It is suggested that short survivorship and random search patterns cause the observed relationships between the percentage of infected hosts and the number of parasites per host with host density. The data fit previous models of parasitism based on random encounters very well.

INTRODUCTION

Members of the molluscan family Eulimidae are almost entirely parasitic in habit. They commonly infest echinoderms, especially holothurians and asteroids, which are apparently very accessible hosts (Baer,

1971). *Balcis aciculata*, *B. cumingi* and *B. paesei* from Hawaii all parasitize echinoderms (Morris, 1966). *Balcis rutila*, found from Alaska to Baja California, is parasitic on starfish. *B. shaplandi*, a common parasite on the asteroid *Archaster typicus*, exhibits selective site segregation, always attaching to either the supramarginal, dorsolateral or the extremities of the arms (Morton, 1976).

Balcis catalinensis (Bartsch) lives in shallow waters from Santa Rosa Island, California to Mazatlan, Mexico, inhabiting sand substrates. Prior to this study, only dead shells have been found; the ecology of this small gastropod has never before been done. The purpose of this study is to evaluate the relationship between *B. catalinensis* and the holothurian *Brandtothuria arenicola*. This is the first report of *B. catalinensis* as a parasite and the first parasite found in association with *B. arenicola*.

MATERIALS AND METHODS

The study area: The research reported here was performed in the Bay of La Paz, Baja California Sur, Mexico, from March 1979 through April 1980. Monthly collections were made from 4 permanent sampling locations (Fig. 1.). Cardoncito and Punto Diablo, located along the coast, are vertical cliffs which drop off to approximately 10 m depth. A rocky substrate below the cliffs persists to a sandy bottom 15 m. Piedra Ahogada is a large rock outcropping rising from 15 m to 1.5 m below the surface of the water at high tide in the mouth of Puerto Balandra; the uppermost .5 m is exposed during extremely low tides. The sides of the outcropping drop precipitously to a sandy bottom. El Farito is a small island approximately .5 km from shore. The windward side is a vertical submarine cliff extending to 10 m; below that a rocky substrate continues to well below 30 m, the limit of our diving observations. The leeward side is a gently sloping rocky bottom falling to between 10 m and 15 m.

Field Procedures: The density of *B. arenicola* in the field was de-

terminated by 10 m linear transects stretched across the benthos. Transects were run at each location from .5 m below the surface of the water, the upper limit of *B. arenicola* to depths of 30 m. A diver swam along each transect and counted the number of holothurians lying completely or partially within 1 m of the line. Only one side of the transect line, determined by the flip of a coin, was sampled.

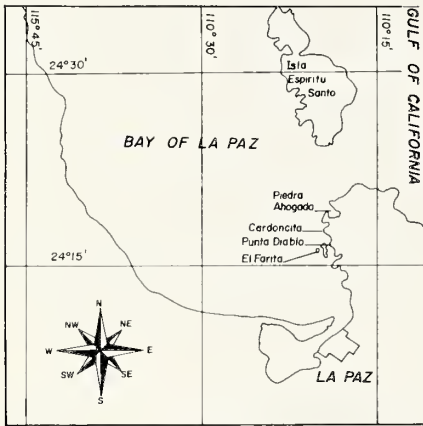


Figure 1. Location of sampling sites with in the Bay of La Paz.

The top 3 cm of sediment were then sampled in a 1 m² quadrat at the depth where holothurian density was highest, returned to the laboratory and analyzed for the presence of live parasites to determine whether *Balcus* is an obligatory parasite. The collection was taken where holothurian density was highest, because it was reasoned that the probability of finding parasites in the sediment would be highest in these zones.

Lab Procedures: Specimens of the holothurian *B. arenicola* were placed in glass or plastic containers to prevent loss of parasites through defecation, regurgitation or physical handling. The live holothurians were transported to the laboratory and measured to the nearest .1 cm. The entire body cavity and all internal organs, external surfaces, and feces were carefully inspected for parasites which were counted, identified, measured to the nearest .5 mm, and separated into groups according to their location in or on the host.

Some live specimens of *B. catalinensis* were removed from healthy hosts and placed in a small aquarium to determine their time of survivorship apart for the holothurian. As the parasites died, they were measured, dissected, and their internal anatomy studied. In another experiment an animal was inspected 6 hours after death to determine if *Balcis* leaves a dead or dying host.

The searching behavior of *B. catalinensis* was investigated using a modified aquarium as the experimental chamber (Fig. 2). The aquarium was divided into two equal parts by an impermeable partition through which a hole was cut at one end. The partition extended 10 cm higher than the level of the water, which was allowed to flow freely through the hole. One side of the aquarium was marked in a grid system so the movements of the parasite could be quantified; one positive point was awarded for each column or row the gastropod moved towards the hole and a negative point was awarded for movement away from the hole. A t-test was then used to determine whether or not there was a significant difference in the movement of *B. catalinensis* between treatments.

The first treatment consisted of placing one holothurian in the aquarium 10 minutes before adding 10 parasites to the other side. Treatment 2 was the introduction of the holothurian 20 minutes before the parasites, and treatment 3 was the placement of the parasites in the aquarium 5 minutes prior to introducing the holothurian. The control consisted of parasites at one end of the aquarium without hosts at the other end.

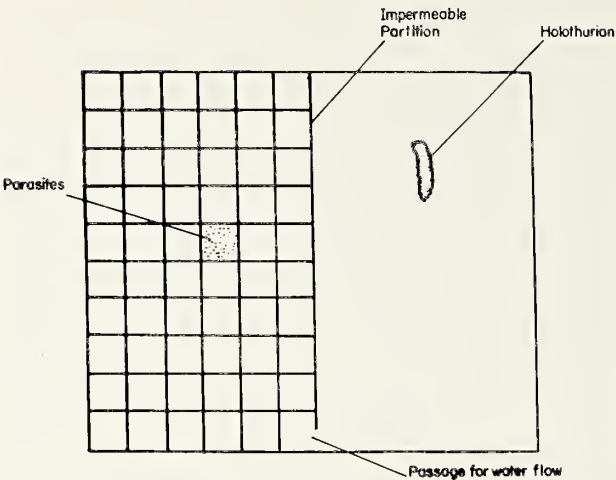


Figure 2. Experimental aquarium showing grid systems used to measure the searching behavior of *B. catalinensis*. The passage for water was cut through only the lower half of the partition, which extended 10 cm above the water surface.

Brand (1980) reports that *B. arenicola*, is an unselective deposit-feeder, consuming detritus, foraminifera and other loose debris such as shell fragments and sea urchin spines; organic detritus is the most important food item. The amount of organic material in the stomach of *B. arenicola* is nearly identical to that of bottom sediments, indicating that the holothurian does not selectively ingest sediments containing large amounts of organic detritus. By comparing the amount of organic material in stomach contents and feces it was discovered that *Brandothuris* assimilates 38.2% of the organic detritus it ingest (Brand, 1980).

It was reasoned that the presence of large numbers of parasites affects the efficiency with which the holothurians are able to assimilate organic materials. Therefore, a group of 5 to 10 holothurians was collected from each of 3 different sites with in the Bay of La Paz, and placed in numbered plastic bags. Feces from them were placed in glass jars with corresponding numbers. A sediment sample was also taken from near each holothurian. The organic content of sediment samples and feces was measured by the Chromic Acid Oxidation method of Holmes and McIntyre (1974) and assimilation efficiencies determined by

$$\frac{\text{organic content of sediment}}{\text{organic content of feces}} \times 100\%.$$

The number of parasites on and in each holothurian was then counted.

RESULTS AND CONCLUSIONS

Balcis catalinensis attains an average length of 3 mm. The shell is whitish with 9 or 10 whorls and is transparent. It is high spired, polished, and the last 4 whorls are bent slightly to the right (Fig. 3A). Sutures are indistinct and the aperture ovate. The visceral mass is reduced, but the brood chamber is large, comprising almost 1/2 of the remaining visceral mass. *B. catalinensis* possesses a pseudopallium which envelops from 1/3 to 1/4 of its proboscis. The periostracum is reduced to a thin transparent plate and the foot, while still present, is vestigial (Fig. 3B.). The eyes are smaller, yet similar, to related free-living members of the genus.

Balcis was never found alive in sediment samples from any station. Shells were not even very common, ranging from 3/m² at El Farito to 1/m² at Piedra Ahogada and Punta Diablo. Parasites were also com-

pletely absent from feces collected in the field and aquaria, suggesting that it is an obligatory parasite.

Throughout the Bay of La Paz, the eulimid prosobranch, *Balcis catalinensis*, is a common parasite on exterior surfaces and in the stomach of the holothurian *Brandtothuria arenicola*. *B. catalinensis* is found on both dorsal and ventral surfaces, its proboscis penetrating into the external papillae. The papillae are not swollen. Although found on exterior surfaces of a large percentage of holothurians, less than 1/5 of the total number of parasites are located on the exterior of the host; the remaining 4/5 are found in the stomach.

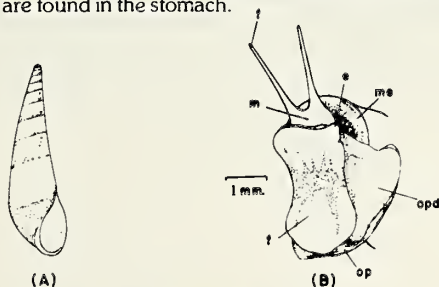


Figure 3. (A) Shell of *Balcis catalinensis*. (B) the whole animal removed from shell in ventral view. e, eye; f, foot; me, mantle edge; op, operculum; opd, operculigerous disc; t, tentacle.

The parasite was observed entering through the hosts' mouths. Once inside the stomach, *B. catalinensis* inserts its proboscis into the interior surface of the stomach wall and apparently feeds on tissue fluids as is characteristic of members of the superfamily, Aglossa. The endohabitat of *B. catalinensis* is in keeping that of most parasitic molluscs, particularly the Pyramidellidae (Fretter and Graham, 1949; Morton, 1976).

There is a significant correlation between the number of parasites found in the stomach and the length of the host, the smallest holothurians (11-15 cm) containing an average of 9 parasites whereas the largest size group (40-45 cm) carried an average of 26 (Fig. 4). This correlation explains 43% of the variability in the data and is significant at $p < .01$. Only size-group 5 did not fit the pattern perhaps because the sample size was smaller than for other groups.

There is no correlation between the number of parasites in the stomach and the depth at which the holothurian was collected (Fig. 5), nor is the percentage of infected hosts significantly related to the depth at which *Brandtothuria* was captured (Fig. 6). The percentage of infected

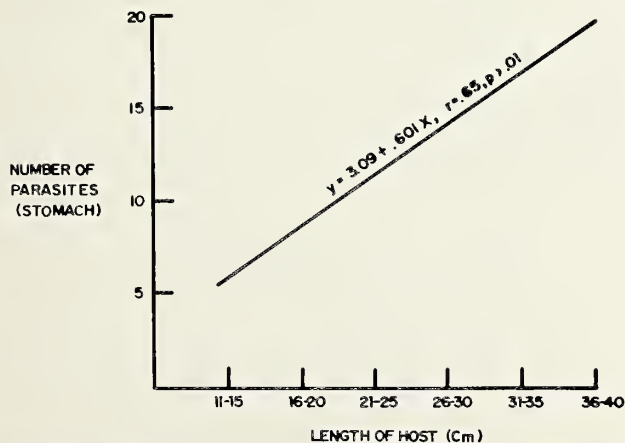


Figure 4. Correlation between the number of parasites located in the host's stomach and length of the host.

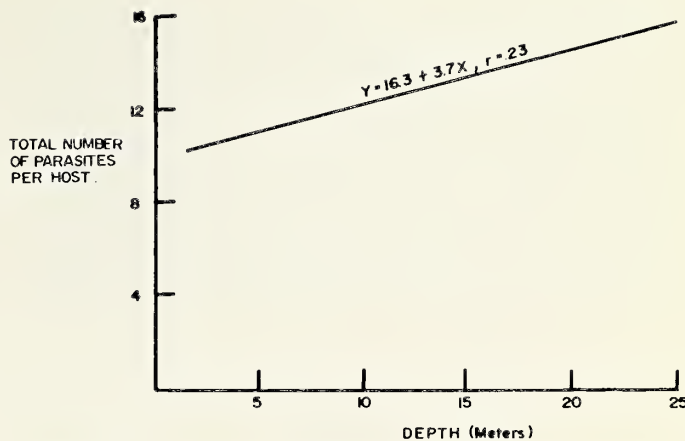


Figure 5. Correlation between number of parasites per host and the depth at which the host is collected.

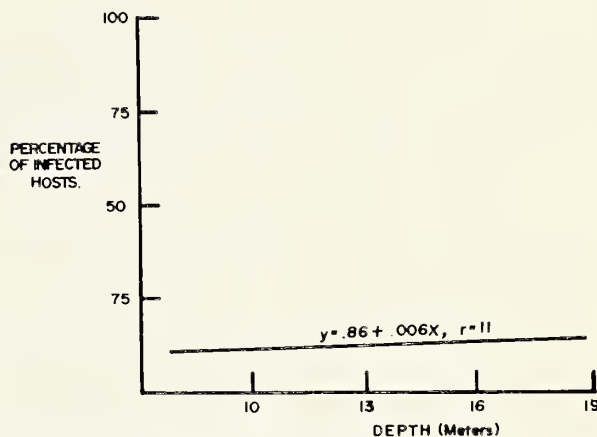


Figure 6. Correlation between the percentage of infected hosts and the depth at which the host is collected.

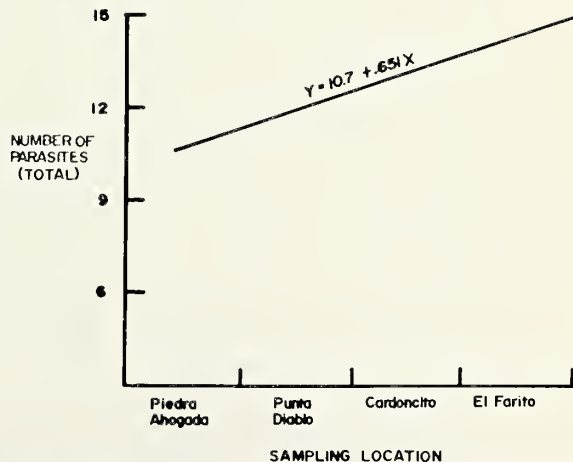


Figure 7. Relationship between the total number of parasites per host and sampling location.

hosts for all stations combined is 93%, ranging from 100% at El Farito and Cardoncito to 66% at Piedra Ahogada (Fig. 7). The average number of parasites/host is 13.54, varying from 8.5 at Piedra Ahogada to 25 at El Farito (Fig. 8). The location with the smallest percentage of infestation also supports the fewest parasites/host.

It has been shown that the number of parasites/host is closely related to the length of the host. Therefore, to test the possibility that differences between sampling stations are due to differences in the average size of holothurians collected at each station, the number of parasites/host observed was compared to the number expected. The number expected was determined by finding the average length of *Brandiothuria* collected at each station and using figure 4 to predict the number of parasites

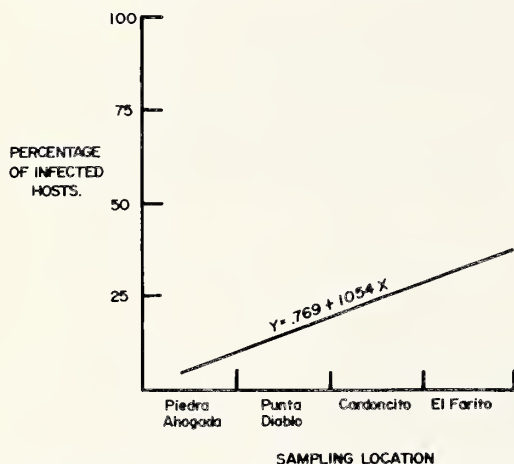


Figure 8. Relationship between the percentage of infected hosts and sampling location.

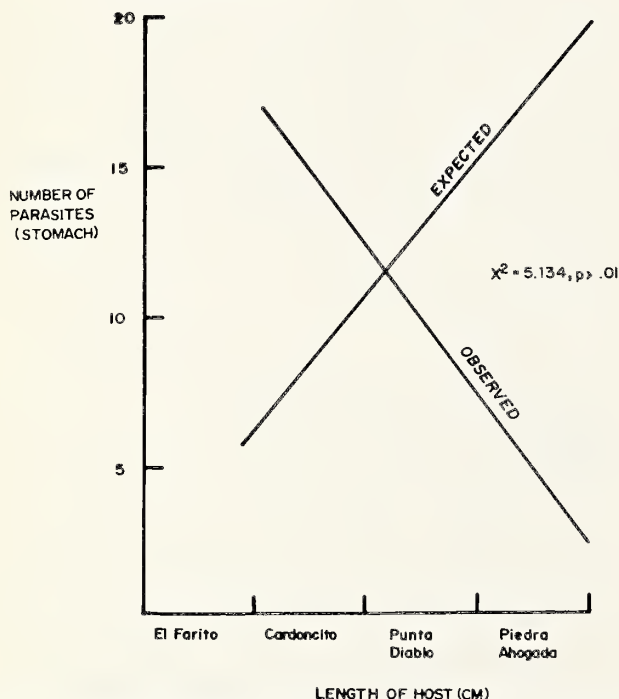


Figure 9. Relationship between the average number of parasites per host observed at each sampling station and the average number expected, based on the average length of holothurians collected at each sampling site.

expected on hosts of that size. When the data are plotted together on the same graph, it is readily apparent that sampling bias is not responsible for the relationship (Fig. 9), and χ^2 -test indicates that H_0 should be accepted; that differences are not due to sampling bias.

The percentage of infected hosts is highly correlated with host density ($p < .1$, $r = .45$) as is the number of parasites/host ($p < .01$, $r = .90$) (see figures 10 and 11). The relationships between percent infection and number of parasites/host with sampling site may therefore be caused by variations in host density (compare figures 7 and 8 with figures 10 and 11).

Host density, then, is the factor most strongly affecting the relationship, and we wished to examine the causal mechanism. Consequently, the survivorship of *Balcis* separated from *Brandiothuria* was investigated.

Parasites normally have a very limited survival time apart from the

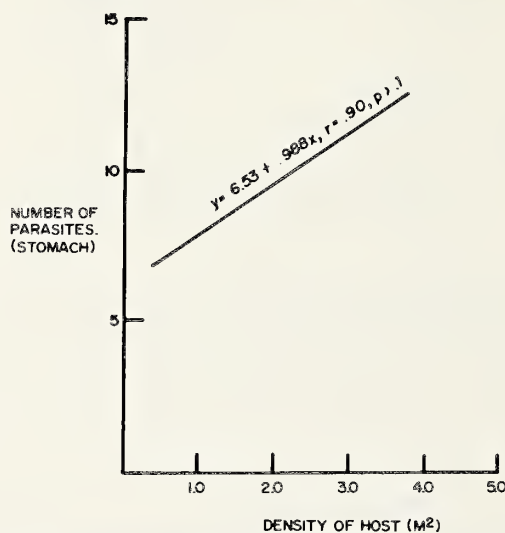


Figure 10. Correlation between the number of parasites found in the stomach per host and host density.

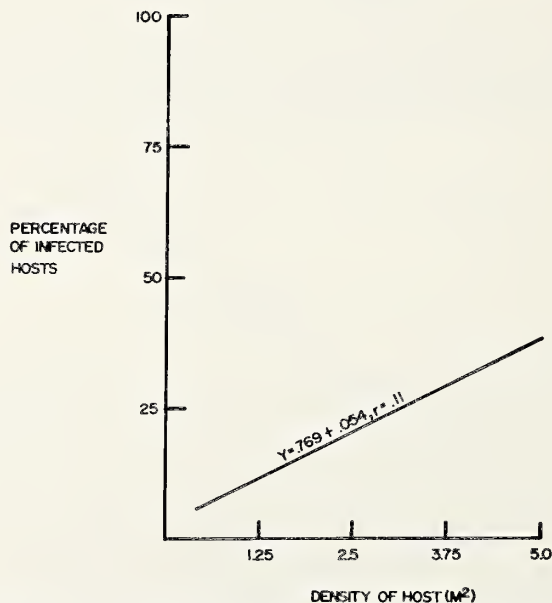


Figure 11. Correlation between the percentage of infected hosts and host density.

host. It has also been demonstrated that dying hosts and hosts held in captivity either discharge their parasites or the parasites evacuate the host (Baer, 1971). Observations of *B. catalinensis* associated with holothurians held in aquaria indicate that the parasite leaves or is discharged by dying hosts, leaving through the mouth. No parasites are found in or on dead holothurians.

B. catalinensis survives an average of only 2 days apart from *B. arenicola* and there is no relationship between length of the parasite and its survival time (Fig. 12). Using length as an indirect measure of age, the data indicate that juveniles and adults have a similar limited period of survivorship separated from *B. arenicola*, and that reinfection must occur within approximately 2 days.

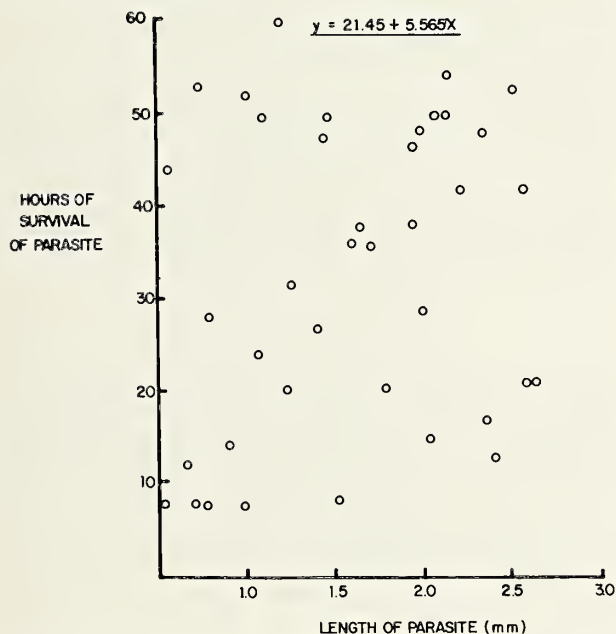


Figure 12. Relationship between time of survivorship of the parasite apart from the host and length of parasite.

The probability of encountering a host in such a short time span would increase if the parasite were able to detect its host at some distance away from the holothurian. Therefore, the searching behavior of *B. catalinensis* was investigated using the modified aquarium shown in figure 2. Any substance omitted by *B. arenicola* would be distributed along a concentration gradient as it passes through the opening in the partition. If *B. catalinensis* is able to chemically sense the presence of *B. arenicola*, the snails would move up this gradient in search of the host, and the number of points awarded would be high. By contrast, inability to chemically detect a host would result in random search patterns and

Treatment	Total points	$\bar{X}$	S	N
1	31	3.1	2.40	10
2	30	3.0	2.51	10
3	22	2.2	2.14	10
Control	19	1.9	2.01	10

Figure 13. Searching behavior of *Balcis catalinensis* under 4 experimental conditions. There is no significant difference between any of the treatments at $p = .1$ using a t-test.

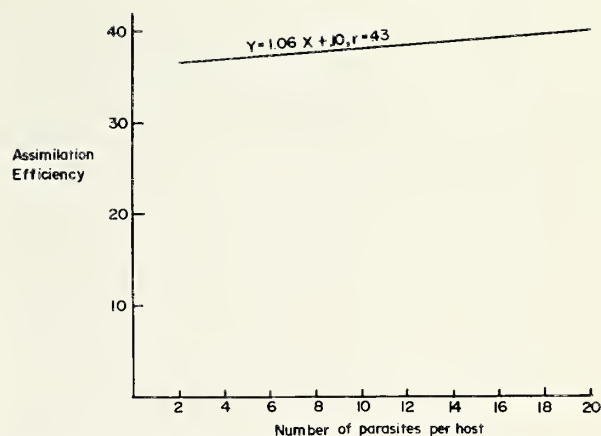


Figure 14. Regression line expressing the relationship between efficiency with which organic detritus is assimilated and the number of parasites per host. The correlation is not significant at $p = .1$.

lower point scores, there being an equal probability of moving away from the opening as moving towards it. The results clearly show that there was no significant difference in the searching behavior of *B. catalinensis* between experimental treatments and demonstrate that the parasite randomly encounters its host (Fig. 13).

DISCUSSION

Treating each parasite found in the stomach as a separate, successful infection episode, both the percentage of infected hosts and the frequency of infection are highly correlated with host density. This is apparently caused by the short survival time of *B. catalinensis* apart from *Brandothuria* and the random search pattern used by the parasite.

The probability of finding 1 host in X chances is $1/X$, whereas the probability of discovering either of 2 hosts would be $2/X$, and so on. Thus, as the number of hosts increases, so does the probability of their being encountered by a randomly searching parasite. The average time spent searching for a host would decrease as host density increases because the average distance from any point in area A to a host would be inversely proportional to host density. Therefore, the probability of a randomly searching microgastropod finding a host within a limited time span would be directly related to host density.

A more rigorous examination of parasitism from a probabilistic standpoint is found in the model of Stoy (1932). According to this model, the number of hosts parasitized per area M (zM) is given by $zM = MX(1 - (1 - 1/MX)^{nM})$, where MX is host density and nM is the frequency distribution of n parasites within an area M . Again, treating each parasite found on or in *B. arenicola* as one separate infection data from the present study were used to generate a regression line using Stoy's (1932) model. This line was then compared to the regression line relating the total number of parasites/host to the density of *B. arenicola* (Fig. 15). The closeness of fit is remarkable, the slope of the lines differing by a factor of only .012X. This demonstrates the general applicability of Stoy's model and the sensitivity of host-parasite relationship to host density.

The difference in slope between the two lines may be explained by the influence of host size, which significantly affects the number of parasites/host in the present study (see Fig. 4). Host size is often an important factor in parasitic relationships, especially in regards to number of parasites/host (Davey and Gee, 1976; Christensen and Hurley, 1977), but it is not included in Stoy's model.

Parasites commonly cause reduced fecundity, lower metabolism,

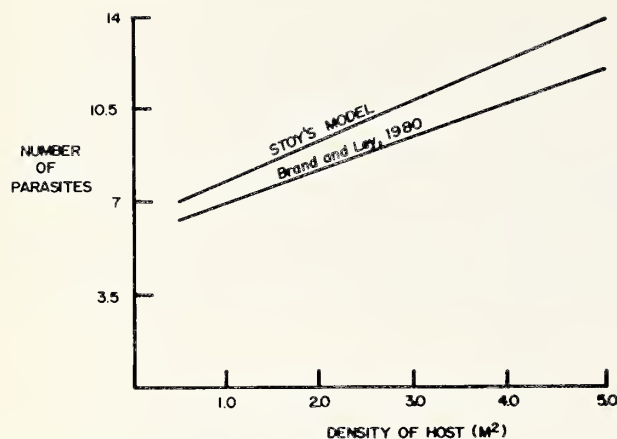


Figure 15. Relationship between number of parasites per host and host density, showing the close fit between the data and the model of Stoy (1932).

and decrease the host's ability to assimilate food items. Rarely, however, is the host killed. *Balcis catalinensis* infests the stomach of the holothurian *Brantothuria arenicola*, which suggests the possibility that the parasite may interfere with the digestion or assimilation of food consumed by the host. Assimilation efficiencies of similarly sized holothurians collected from throughout the Bay of La Paz varied from 36% to 39%, increasing with the number of parasites/host (Fig. 14). The regression line explains 43% of the variability in the data, but is not significant at $p = .1$. It is therefore concluded that the presence of *B. catalinensis* does not inhibit the assimilation efficiency of *B. arenicola*. The effects of parasitism on productive output and respiration are currently being investigated.

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CORRELATION OF UNIONID MUSSELS WITH BOTTOM SEDIMENT COMPOSITION IN THE ALTAMAHA RIVER, GEORGIA

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INTRODUCTION

The Altamaha River system is the largest in Georgia with a drainage area of approximately 37,000 km² and average discharge of 400 m³/sec (U.S. Geological Survey, 1974). The river is formed by the confluence of the Oconee and Ocmulgee Rivers southeast of Macon and flows 215 km through the Coastal Plain to the Atlantic Ocean between Darien and Brunswick, Georgia. The Altamaha is the southern most river of the zoogeographic region defined by H. and A van der Schalie (1950) and further elaborated by R.I. Johnson (1970) and known as the Southern Atlantic Slope region. Johnson (1970) listed 18 species of pearly freshwater mussels, Unionidae, occurring in the Altamaha, 6 of which are endemic.

Most investigators and collectors of freshwater mussels are aware of habitat preferences of various species inhabiting the same general areas of a river. Clench (1962) reported finding *Elliptio shepardiana* at "mud stations" and *Canthya spinosa* on shallow sandbars in the Altamaha River. (*Canthya spinosa* is commonly referred to in the literature as

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Elliptio spinosa, but, according to David H. Stansbery, pers. comm., the genus *Canthya* is appropriate). Hamman (1972) reported finding *Strophitus undulatus*, *Anodonta cataracta* and *Elliptio complanata* only in soft but firm sediment of sandy clay in central New York.

Coker *et al.* (1921) emphasized the importance of the bottom sediment on the occurrence of mussels in their statement, "It may, therefore, be supposed that fresh-water mussels, like other animals, are adapted rather definitely to particular conditions of the environment;... that a mud bottom supports certain species, while a firmer soil is required by others." They also point out the even more restrictive habitat requirements of the young mussels. "Adult mussels in some cases thrive, or continue to live at least, in environments where the young would perish, for delicately balanced conditions are required by very young mussels of many species, and only where these conditions exist can a mussel bed originate or perpetuate itself." Coker *et al.* (1921) listed 62 freshwater mussel species along with the general composition of the bottom in habitats where they occurred.

The composition of bottom sediment is the major factor controlling the occurrence of benthic organisms (Hynes, 1970). Sediment composition along a river bottom results from the interaction of geological, topographical, climatic, edaphic and hydraulic characteristics of the drainage basin. Stream velocity has a major and immediate influence on the movement of sediments. The competence and capacity of the stream change with its load, and the load is often a direct result of man's

In the study reported here, nine species of Unionidae were found to occur in varying densities within seven sample sites. The sediment characteristics of each site were determined, and the occurrence of each mussel species was related to the sediment composition.

Sediment samples were collected at each site using an inverted tennis ball can as a coring device. It had holes drilled in the closed end and a rubber diaphragm affixed to allow water to exit as the can was being pushed into the sediment; as the can was withdrawn the diaphragm acted

The relationship between mussel species and sediment composition was determined by multiplying the density of each species at each site by the fractional distribution of sediment particle size at each site and summing the values for each half Phi interval.

Nine species of Unionidae were collected: *Lampsilis dolabraeformis* (Lea), *Canthyrta spinosa* (Lea), *Elliptio hopetonensis* (Lea), *Elliptio dariensis* (Lea), *Elliptio shepardiana* (Lea), *Lampsilis splendida* (Lea), *Alasmidonta arcuata* (Lea), *Anodonta gibbosa* Say, and *Anodonta couperiana* (Lea). Assistance with identifications was obtained from Dr. Joseph P.E. Morrison, Smithsonian Institution, and Dr. Grace J. Thomas, University of Georgia. The percentage composition of each species at each of the seven collecting sites is shown in Table 1.

Percent

[illegible]

Sites 10 and 12 were sandbars adjacent to the main channel and had predominately coarse to very coarse sand sediment. Sites 6 and 8 were at the upstream ends of sandbars near the river bank and consisted primarily of medium to fine sand. Sites 15 and 11 were along the river bank among overhanging willow trees and consisted of fine sand and silt. Site 18 was in a slough with silt and clay sediment. Fig. 1 shows the sediment size distribution at each site.

The number of mussels of each species found at each site was multiplied by the sediment size fractions at the sites and the resulting numbers were summed for all sites. This operation provided a value for the abundance of each species relative to the sediment size distribution (Fig. 2).

DISCUSSION AND CONCLUSIONS

Some species of mussels are more habitat restricted than others. *Anodonta gibbosa* was found only in a protected slough with a sediment consisting primarily of silt and clay. *Anodonta couperiana* occurred at the same site as *A. gibbosa* but also in areas of the main river consisting of fine sand and silt. *Alasmidonta arcuata* was less restricted and occurred along with *A. couperiana* in the main river. Young *A. arcuata* were found on sandbars of coarse sand, but most occurred near the riverbank in finer sediments.

Elliptio dariensis and *E. hopetonensis* generally occurred together in highest densities along the protected river banks in fine sand to coarse silt sediment. *E. Hopetonensis* dominated those areas with only a few *E. dariensis* being found. *Canthya spinosa* was found only on sandbars of very coarse to fine sand. It appeared to be restricted to swiftly flowing

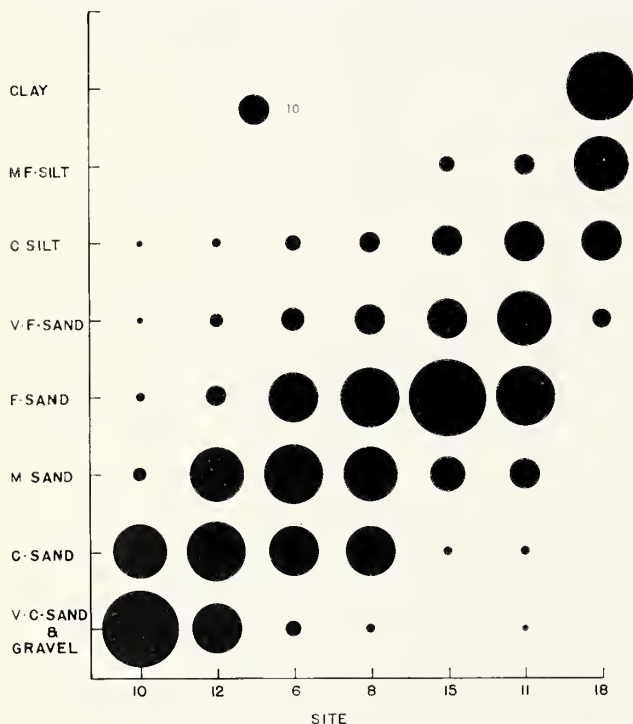


Figure 1. Sediment particle size distribution for the Altamaha River collection sites. The area of each dot represents the percentage of the sediment by weight having the indicated particle size. A standard area is indicated by the dot marked 10%. The abbreviations V.F, F, M, C, and V.C represent very fine, fine, medium, coarse, and very coarse particle size designations used by Hynes (1970).

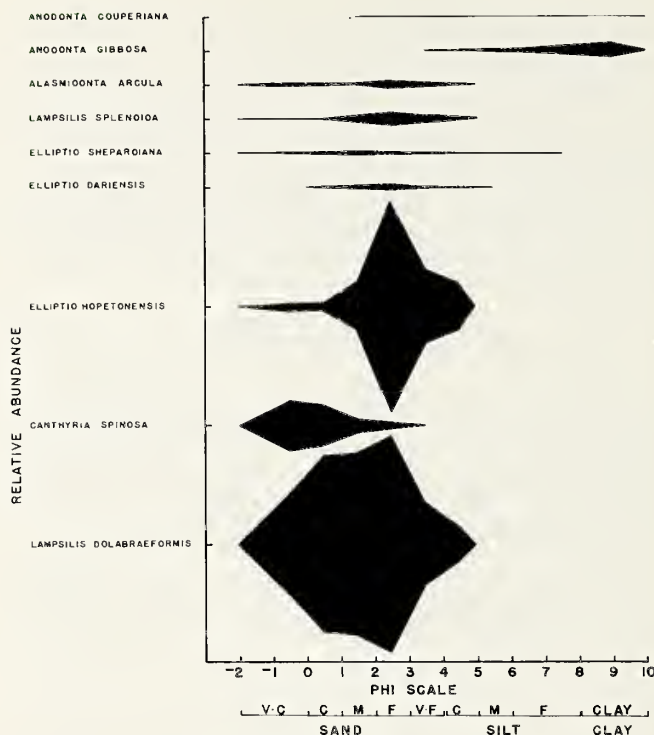


Figure 2. Relative abundance of freshwater mussels with respect to sediment particle size in the Altamaha River. Particle size is indicated on the Phi scale where Phi is the negative base 2 logarithm of the particle diameter in mm. Sand and silt are subdivided into very coarse, V.C, coarse, C, medium, M, fine, F, or very fine, V.F, according to Hynes (1970).

water on sandbars. *Lampsilis splendida* was found in association with *E. hopetonensis* primarily near the river banks in fine sand with some coarse silt.

The most abundant mussel was *Lampsilis dolabraeformis* which was found generally distributed throughout the main river on sandbars and along the river banks. It occurred in highest densities in coarse to fine sand and was the most mobile mussel, frequently being seen migrating to deeper water.

Those species of mussel with the greatest restriction of habitat are the most likely to be affected by habitat alterations. *Canthya spinosa* might be highly susceptible to siltation.

This study provides distributional data and habitat characteristics of six endemic mussels of the Altamaha River, Georgia, in 1968 when the mussels were plentiful. Since the study was completed changes have occurred which have resulted in a marked decline in the mussels. A nuclear steam electric plant was constructed at the study area, and the Asiatic clam, *Corbicula fluminea*, invaded (Gardner, et al., 1976, Sickel, 1979) and became abundant during the period of mussel decline. Changes in sediment composition appear to have occurred. Additional studies are needed to determine if any reproducing populations of mussels remain in the Altamaha River and also to support a petition to place the six endemic species on the federal endangered species list. The six endemic species which have undergone a drastic decline in number are *Canthya spinosa*, *Lampsilis dolabraeformis*, *Elliptio hopetonensis*, *Elliptio shepardiana*, *Alasmidonta arcuata* and *Anodonta gibbosa*.

ACKNOWLEDGEMENTS

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FRESHWATER MUSSEL GLOCHIDIA FROM LAKE WACCAMAW, COLUMBUS COUNTY, NORTH CAROLINA

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INTRODUCTION

Lake Waccamaw, an elliptical lake approximately 58 kilometers west of Wilmington in Columbus County, North Carolina, is the largest natural lake in the state, encompassing about 3,600 hectares. It has a maximum depth approaching 3.3 meters. A detailed physical description of the lake and the relationship of it to the other North Carolina bay lakes is found in Frey (1948, 1949) and Louder (1958).

The known molluscan fauna of the lake includes eleven naiad and three gastropod species, several of which are endemic to the lake (Stansbery and Clench, 1978). The uniqueness of this molluscan fauna and its description have been discussed by Jennewein (1971), Fuller et al. (1976), Fuller (1977), and Tuelings and Cooper (1977); however, the biology, ecology and molluscan interrelationships of the Waccamaw endemics are poorly understood.

Fuller (1977) stressed a need to know the glochidial hosts of the Lake Waccamaw endemic naiads as a means of being able to conserve such species. At present no fish species (in the lake) has been documented as the host for any Lake Waccamaw naiad species. Further, glochidial descriptions and reproductive history of most naiads occurring within the lake and its basin are unpublished. Recognition of a fish as infected with a specific mussel glochidia is difficult without an adequate morphological description of the glochidia of each available mussel species and knowledge of the reproductive periodicity of each. The purpose of this paper is to describe glochidia recently found during a present ongoing survey of the Lake Waccamaw molluscan fauna.

METHODS

Modified, randomized, benthic samples from Lake Waccamaw are taken at quarterly intervals using a suction-lift type dredge. Collecting bags, of either 1.6 or 6.4 mm stretch-bar mesh screening, are attached to the dredge and substrate is screened within either 1/16 or 1/4 m² sampling frames to a depth of 15 cm. Non-dredge but quantitative shallow water substrate samples occasionally are taken. Monthly tissue-condition studies of *Elliptio waccamawensis* (Lea, 1863) (50 individuals each from several differing lake locations) furnish additional information

concerning marsupial presence. Data from preserved specimens collected in 1978 by the senior author and from a 1979 Waccamaw River collecting trip are included in the data here.

Glochidia used in this study were teased from portions of marsupia removed from the preserved naiads. "AGW", an ethyl alcohol glycerin mixture recommended by Dr. D.H. Stansbery, (pers. comm.) Ohio State University, was used to preserve all collected mollusks and naiad glochidia. Polaroid and 35 mm photographs were taken through a Wild M5 stereomicroscope using a Wild MKa4 camera. Classification of Atlantic drainage North Carolina naiads is in an unsettled state at present. Lake Waccamaw naiad names used in this paper are those proposed by D.H. Stansbery (pers. comm.); naiad identifications were authenticated also by D.H. Stansbery.

RESULTS

Glochidia were collected from marsupia of *Elliptio waccamawensis*, *E. fisheriana* (Lea, 1838), *E. raveneli* (Conrad, 1834), *Toxolasma pullus* (Conrad, 1838), *Lampsilis* sp., *Lampsilis crocata* (Lea, 1841), and *Leptodea ochraceus* (Say, 1817). Glochidia of *E. folliculata* (Lea, 1838), *E. lanceolata* (Lea, 1828), *Villosa ogeecheensis* (Conrad, 1849), and *Anodonta teres* Conrad, 1834 were not seen; however, these latter species have been collected infrequently during this program. *Unio merus obesus* (Lea, 1831), found by Dr. D.H. Stansbery in Lake Waccamaw (pers. comm.), has yet to be found in any of our Waccamaw samples.

Elliptio waccamawensis glochidia (Figure 1): dimensions are found on Table 1. Hinge shape varies from straight to slightly concave. The suboval hookless glochidia are marginally bilaterally asymmetrical. Shape and size of this glochidium appears identical to that of *E. fisheriana*. Marsupia were observed in May, June and August 1979. May and August 1979 marsupia were not examined for glochidia, but glochidia were observed in June. In 1980, marsupia containing both eggs and glochidia, were present in May, June and July; no marsupia were observed in August.

Area variation in reproductive period of *E. waccamawensis* was observed in the 1980 sampling. May trawl samples in the central deep-water, peat-bottom area contained numerous marsupia with glochidia while tissue-condition samples from peripheral areas in the southeast, northeast and northwest portions of the lake contained no *E. waccamawensis* with marsupia. In June, 46% of the southeastern tissue-condition sample had a marsupium; of those with a marsupium, 35% contained glochidia. This same location in July had 34% with a mar-

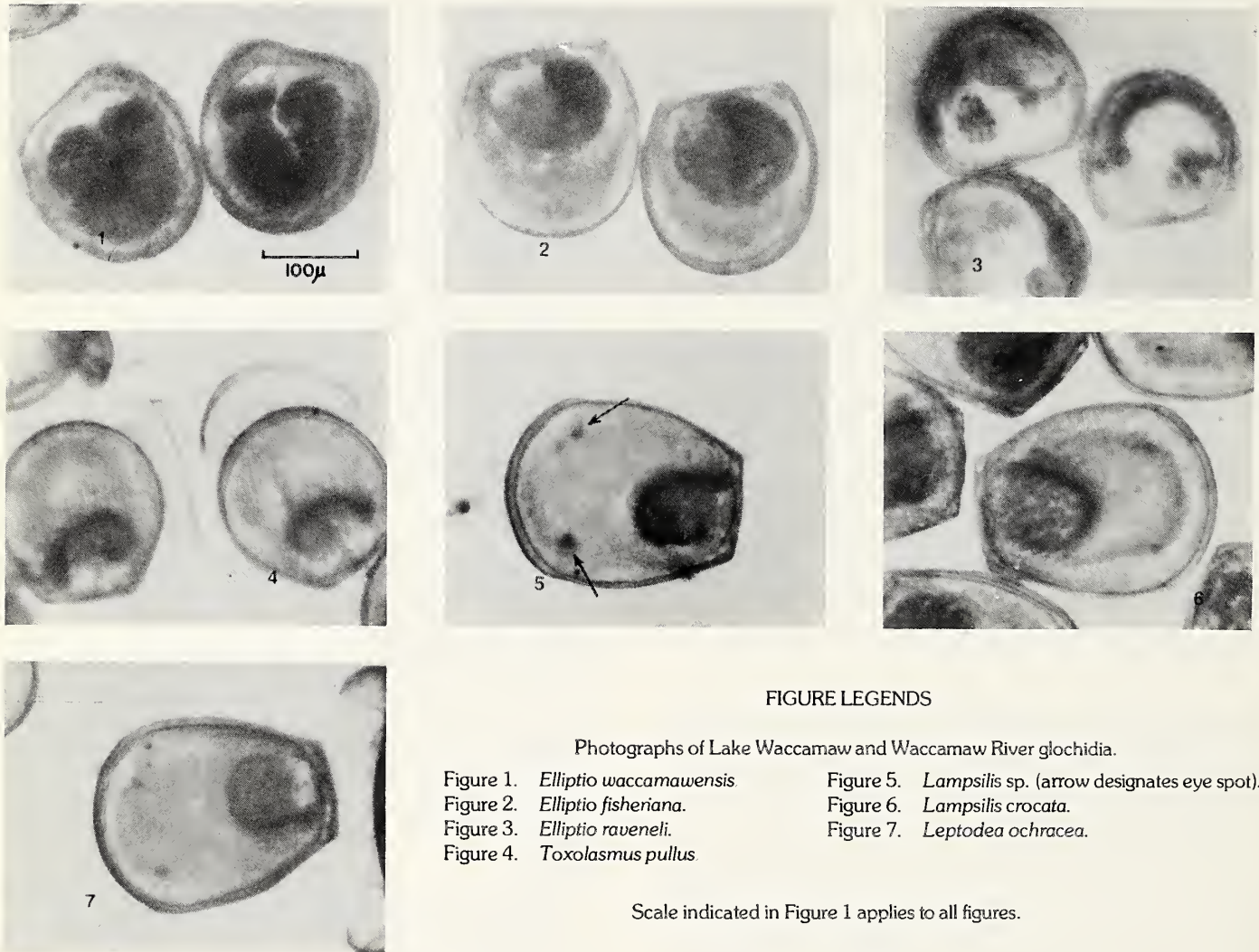


FIGURE LEGENDS

Photographs of Lake Waccamaw and Waccamaw River glochidia.

- | | |
|---|---|
| Figure 1. <i>Elliptio waccamawensis</i> | Figure 5. <i>Lampsilis</i> sp. (arrow designates eye spot). |
| Figure 2. <i>Elliptio fisheriana</i> . | Figure 6. <i>Lampsilis crocata</i> . |
| Figure 3. <i>Elliptio raveneli</i> . | Figure 7. <i>Leptodea ochracea</i> . |
| Figure 4. <i>Toxolasmus pullus</i> | |

Scale indicated in Figure 1 applies to all figures.

supium and 65% of the marsupia contained glochidia. Tissue-condition samples in June and July from the northeastern and northwestern lake areas had six or fewer percent with a marsupium present and, when glochidia were present, the glochidia seemed in poor condition. June and July data were unavailable for the central area of the lake. No adequate explanation has been formulated for this disparity between areas in relation to percent marsupial occurrence.

*Elliptio fisheriana*¹ glochidia (Figure 2): dimensions are found on Table 1. As suggested earlier, these measurements and ratios appear identical to those of *E. waccamawensis*. The hinge shape is a straight line; the hookless suboval glochidia appear somewhat bilaterally asymmetrical. Comparison of photographs and camera-lucida drawings of the two species suggested no recognizable shape difference; however, the adductor muscle may be closer to the hinge line in *E. fisheriana* than in *E. waccamawensis*. The validity of this as a distinguishing characteristic is unresolved. Recent nonrecorded observations of a number of glochidia show variability in the distance of the adductor muscle from the hinge line within the same species. Glochidia were observed only in July, 1978.

Elliptio raveneli glochidia (Figure 3): dimensions are found on Table 1. Hinge is straight to moderately convex. Shape of this hookless suboval glochidium is slightly bilaterally asymmetrical. Lengths and heights of *E. raveneli* are smaller and rarely overlap the data range of *E. wac-*

camawensis and *E. fisheriana* (Table 1). Hinge lengths of all three *Elliptios* are similar. Hinge length/length and hinge length/height ratios of *E. raveneli* are greater than those of the other two *Elliptios* and the height/length ratio is smaller.

For the sake of accuracy, it must be pointed out that while all *E. waccamaw* and *E. fisheriana* glochidia data are from Lake Waccamaw specimens, the above *E. raveneli* glochidia are from specimens collected August, 1979 in the Waccamaw River. Gravid *E. raveneli* have not been collected in Lake Waccamaw by the authors.

*Toxolasmus*² *pullus* glochidia (Figure 4): dimensions are found on Table 1. Hinge shape is straight with a weak convexity caused by the valve umbos extending slightly above the hinge line. Glochidia are hookless, approximately the same size as *E. waccamawensis* and *E. fisheriana*, and distinguishable by their globose shape. This globose condition is caused partly by a relatively short hinge length. Hinge

¹Stansbery (pers. comm.) has recently suggested that a better name for this Lake Waccamaw species might be *Elliptio producta* (Conrad, 1836).

²Baker (1928) states that the name *Toxolasma* is not valid and should be replaced by *Canthadula*.

length/length and hinge length/height ratios of *T. pullus* are considerably smaller than those of the *Elliptios*. Glochidia were collected June, 1979.

Lampsilis sp. glochidia (Figure 5): dimensions are found on Table 1. Hinge shape is straight with the valve umbos extending slightly above the hinge line, giving the line sometimes a false convex appearance. The purse-shaped valves are bilaterally symmetrical and hookless. Eye spots (called "outer hair cells" by Arey, 1920) are evident near the ventral border. Glochidia were collected in April and June, 1979.

Lampsilis crocata glochidia (Figure 6): dimensions are found on Table 1. Hinge shape is straight with valve umbos extending occasionally just beyond hinge line. Valves are bilaterally symmetrical, hookless, and purse-shaped. Eye spots are present near ventral border. Glochidial size and shape approximates that of *Lampsilis* sp. The hinge length is generally larger than that present in *Lampsilis* sp.; this slightly larger condition correspondingly reflects in somewhat higher hinge length/length and hinge length/height ratio values for *L. crocata*: Glochidia were collected in June, 1979.

*Leptodea ochracea*³ glochidia (Figure 7): dimensions are found on Table 1. Hinge line is slightly convex with valve umbos generally not quite reaching hinge line. Valves are bilaterally symmetrical, hookless, and purse shaped. Eye spots are near the ventral border. Glochidial size and shape approximates that of *Lampsilis* sp. and *Lampsilis crocata*. Hinge length values and the ratio hinge length/length and length/height values are smaller in *Leptodea ochracea* than present in the two *Lampsilis* species. Marsupia containing glochidia have been collected only in April and June, 1979.

DISCUSSION

Glochidia of seven of the naiads inhabiting Lake Waccamaw and its basin are described in the preceding, some for the first time. This description should enable progress towards identification of encysted glochidia

³Bereza and Fuller (1975) state that *ochracea* is not in the Genus *Leptodea* but closer related to the Genus *Lampsilis*.

Table 1. LAKE WACCAMAW GLOCHIDIA MEASUREMENT AND MEASUREMENT RATIO DATA. Measurements expressed in "u" (.000 mm); N = numbers of glochidia measured.

SPECIES OF GLOCHIDIA	N	LENGTH		HEIGHT		HINGE LENGTH		HINGE LENGTH/LENGTH		HEIGHT/LENGTH		HINGE LENGTH/HEIGHT	
		Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$
<i>Elliptio waccamawensis</i> (4 specimens)	22	199.9-219.4	209.9	209.8-228.4	217.0	124.9-153.3	144.0	0.57-0.74	0.69	0.97-1.09	1.04	0.59-0.72	0.66
<i>Elliptio fisheriana</i> (1 specimen)	6	202.9-212.2	208.6	213.9-227.4	221.4	142.5-154.5	148.1	0.68-0.74	0.70	1.03-1.09	1.06	0.63-0.70	0.67
<i>Elliptio raveneli</i> (3 specimens)	17	177.0-201.7	188.5	165.6-185.0	176.7	129.1-160.7	142.2	0.68-0.82	0.76	0.88-0.98	0.94	0.72-0.89	0.81
<i>Toxolasmus pullus</i> (1 specimen)	12	194.4-207.1	199.2	212.2-230.3	219.5	104.5-113.5	110.4	0.52-0.58	0.55	1.06-1.14	1.10	0.47-0.52	0.50
<i>Lampsilis</i> sp. (4 specimens)	17	211.1-234.3	221.7	264.8-288.7	275.5	111.0-132.0	120.2	0.50-0.58	0.54	1.18-1.28	1.24	0.40-0.46	0.44
<i>Lampsilis crocata</i> (3 specimens)	8	219.2-235.8	227.4	268.4-294.2	279.7	126.0-143.6	132.8	0.55-0.62	0.58	1.18-1.29	1.23	0.43-0.50	0.48
<i>Leptodea ochracea</i> (3 specimens)	13	213.9-239.8	227.0	263.3-286.9	277.3	102.6-113.9	109.4	0.46-0.50	0.48	1.16-1.28	1.22	0.38-0.42	0.40

Table 2. *Lampsilis* sp. (Lake Waccamaw) vs. *Lampsilis radiata* (various references): COMPARISON OF GLOCHIDIAL MEASUREMENT AND MEASUREMENT RATIO DATA. Measurements expressed in "u" (.000 mm).

SPECIES OF GLOCHIDIA AND REFERENCE	LENGTH		HEIGHT		HINGE LENGTH		HINGE LENGTH/LENGTH		HEIGHT/LENGTH		HINGE LENGTH/HEIGHT	
	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$	Range of data	$\bar{X}$
<i>Lampsilis</i> sp. ¹	211.1-234.3	221.7	264.8-288.7	275.5	111.0-132.0	120.2	0.50-0.58	0.54	1.18-1.28	1.24	0.40-0.46	0.44
<i>Lampsilis radiata radiata</i> (Wiles, 1975) ²	263.45		315.48				0.47		1.20 1.17		0.40	
<i>Lampsilis radiata</i> (Tedla and Fernando, 1969) ²	273		316						1.16			
<i>Lampsilis radiata</i> (Calloway and Turner, 1978) ³	243.38		286.03		127.21		0.52		1.18		0.44	
<i>Lampsilis radiata</i> (Ortmann, 1919) ²	220-230		270-280									
<i>Lampsilis luteola</i> - possible syn. of <i>Lampsilis radiata</i> (Ortmann, 1919) ²	230 250		280 290						1.20 1.16			
<i>Lampsilis radiata stilloquidea</i> (Clarke, 1973) ²	240-260		260-300									

¹ Repeated from Table 1.

² Length and height measurements as published, ratio values calculated as part of present study.

³ Values calculated from measurements made from glochidial photograph.

in fish species from the lake and its basin. Consequent identification of fish hosts of some of these endangered naiads may result, facilitating appropriate conservation methods capable of perpetuating viable populations of these species.

The glochidia of three *Elliptio* species are described. Only the glochidia of *E. raveneli* (Plate 3) seem separable from *E. waccamawensis* and *E. fisheriana*. The glochidia of this species are smaller in length, height, and height/length ratio than the other two species.

The glochidia of two *Elliptios* - *E. folliculata* and *E. lanceolata*, occurring in Lake Waccamaw, have yet to be seen. Johnson (1970) lists *E. fisheriana*, *E. folliculata*, and *E. producta* as synonyms of *E. lanceolata*. Accordingly, it is expected that all of these species will have similar glochidia, glochidia which may be indistinguishable from that of *E. waccamawensis*. Further observations and study are clearly needed with this group.

Glochidia of *E. fisheriana* may have been observed before. Ortmann (1919) gives a glochidial length of 0.2 mm (200u) for *E. cupreus* (Rafinesque, 1820)⁴, which he suggests may be a synonym of *E. fisheriana*. This is a smaller height than we observed and the consequent height/length ratio (1.00) is fractionally smaller than our data indicates. Reardon (1929) includes a drawing of glochidium of an *E. producta*, a possible senior synonym of *E. fisheriana* (Stansbery, pers. comm.). This glochidium has the following ratios: hinge length/length = 0.81, height/length = 0.96, and hinge length/height = 0.85. These ratios are considerably different than the *E. fisheriana* ratios in this study (Table 1).

Time of occurrence of glochidia in the preceding *Elliptios* suggested a tachytictic condition (short-term breeder). Aforesaid data of *E. waccamawensis* does suggest that the time of breeding is not constant but may vary from season to season, and in Lake Waccamaw, between different ecological zones in the same season. As stated earlier, glochidia of *E. waccamawensis* have been found May through July, although marsupia have also been observed in April and August.

Glochidia of *Toxolasmus pullus* have a closer resemblance to glochidia of the *Elliptios* of Lake Waccamaw than to other naiad species. They are readily distinguishable from the *Elliptios* by a globular shape and a shorter hinge line. Hinge length/length and hinge length/height ratios (smaller than in the *Elliptios* - Table 1) are useful for identification. Ortmann (1919), describing the closely related *Toxolasma parvum* (Barnes, 1823), gives a glochidial length of 0.18 mm (180u) and a height of 0.20 mm (200u) which results in a height/length ratio of 1.11. Surber (1915) for the same species has a drawing with a length of 170u and a height of 195u (length ratio = 1.16). These figures approximate those recorded for *T. pullus* (Table 1). The shape of *Lampsilis parva* glochidia, as pictured by Surber (1915), similarly approximates that of *T. pullus* (Figure 4).

Glochidia of the two *Lampsilis* species and *Leptodea ochracea* are similar in general appearance. Their purse-shaped profile easily enables them to be set apart from the globular *Toxolasmus* and the suboval *Elliptios*. Glochidial separation of the *Lampsilis* species and *Leptodea ochracea* seems best accomplished through a comparison of their hinge lengths and the ratios - hinge length/length, hinge length/height. *Lampsilis crocata* is the largest in all three of the above data categories, *Lampsilis* sp. is intermediate in data range, and *Leptodea ochracea* has the smallest values (Table 1).

Lampsilis sp. is believed to correspond to that which Fuller (1977) listed as "'*Lampsilis*' *radiata* (Gmelin, 1791) and *Lampsilis radiata siliquoidea* (Barnes, 1823) have been documented by a number of authors (Table 2). Data presented in Table 2 suggests a possible greater height/length ratio for *Lampsilis* sp. than for the glochidia of *Lampsilis radiata*.

A *Leptodea ochracea* glochidium is pictured by Reardon (1929). Value ratios determined from this drawing are: hinge length/length ratio = 0.71, height/length ratio = 1.32, and hinge length/height ratio = 0.54. Comparison of these figures with the *Leptodea ochracea* data in this study (Table 1) suggest that the Reardon picture is not representative of the *Leptodea ochracea* glochidia found in Lake Waccamaw.

A characteristic of the Genus *Leptodea* is very small glochidia (Baker, 1928). Baker lists the following dimensions for glochidia of *Leptodea fragilis* (Raf., 1820) (type species of *Leptodea*): length = 0.07-0.08mm (70-80 u), height = 0.09-0.095mm (90-95 u). These dimensions are approximately 1/3 the size we describe for *Leptodea ochracea* (Table 1). The shape of *fragilis*, also illustrated in Baker (1928), is more oval than that of the Waccamaw *ochracea* (Figure 7). Thus, the Waccamaw *ochracea* glochidia, both in size and shape, are nearer to glochidia described for the Genus *Lampsilis* than for the Genus *Leptodea*. This strengthens the contention of Bereza and Fuller (1975) that the species *ochracea* is closer related to *Lampsilis* than to *Leptodea*.

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⁴Johnson (1970) believes *E. cupreus* to be a synonym of *E. dilatus* (Rafinesque, 1820).

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AN ELECTROPHORETIC STUDY OF *CORBICULA FLUMINEA* (BIVALVIA: CORBICULACEA) IN THE CATAWBA RIVER

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ABSTRACT

A single population of *Corbicula fluminea* was studied using starch gel electrophoresis. The population was sampled regularly for one year. A small amount of genetic variation was observed at 3 of the 7 loci examined. This variation was organized as very low heterozygosity and moderate polymorphism. This pattern is consistent with the suggestion that *C. fluminea* is self-fertilizing. No differences in banding patterns were found between individuals of different size classes or between those collected at different times of the year. This is the first report of electrophoretic variation in *Corbicula* from this country.

Various aspects of the biology of the introduced Asiatic clam, *Corbicula fluminea*, have recently been the focus of some interest. This interest has involved (1) pragmatic reasons in that it is a pest to industries using rivers (Sinclair, 1971a) (2) theoretical considerations as a recently imported organism which has rapidly expanded its range.

The earliest reported collection in this country was in 1938 from the Columbia River, Washington (Ingram, 1959). Since then, *Corbicula* have apparently spread south and east across the continent (Smith et al., 1979) by a variety of mechanisms. As recently as 1971, *Corbicula* was reported in the literature as being excluded from the middle atlantic states (Sinclair, 1971b). However, biologists for Duke Power Company first reported *Corbicula fluminea* in Lake Wylie on the Catawba River in North Carolina in 1969 (Pace, Personal Communication). Since 1969, *Corbicula* has spread up the Catawba River system.

Recently Smith et al. (1979) reported the results of an electrophoretic study of *Corbicula*. They sampled 18 loci in five populations in this country, two populations from the Philippines, one from Japan, and one from Hong Kong. Polymorphisms were observed at some loci in populations from the orient. There were, however, no polymorphic loci

observed in populations collected in the U.S. The Japanese sample had a relatively high heterozygosity ($H = 0.229$), but all other Asian populations were reported as having "reduced variability" (Smith et al., 1979). they interpreted these data as indication a single founder event as the source of *Corbicula* in this country, and that the spread of *Corbicula* represents a further series of founder events. There was no indication in their study of repeated sampling of populations over a period of time, or of individuals representing different ages or reproductive states in each population. We have not found references to any other electrophoretic study of *Corbicula*.

MATERIALS AND METHODS

A single population of *Corbicula fluminea* in the south fork of the Catawba River, at Lake Wylie, was sampled with an Ekman dredge monthly for one year. The study area was a small cove with a water depth of up to 4 m. The substrate close to shore was a fine gravel and detritus, and further from shore and in the main channel a hard packed clay. Live clams were transported in river water to the laboratory where they were measured and then preserved or prepared for electrophoresis.

Mantle, gill, gonads, shell adductor muscle, and foot were homogenized together in an equal value of cold 0.5 M tris HCL, pH 7.1, buffer (Hornbach et al., 1980a). Horizontal starch gel electrophoresis was carried out in a 12.5% gel in the tris Borate EDTA buffer (pH 9.3) of Ayala et al. (1972). Gels were stained for glutamate oxaloacetate transaminase (GOT), Leucine aminopeptidase (LAP), and total protein (TP) according to the methods of Selander et al. (1971) and Ayala et al. (1972). Interpretation of banding patterns followed that given by Hornbach et al. (1980a).

RESULTS AND DISCUSSION

Sampling was confined to an area of fine gravel where the water depth was 1-1.5 M. The population was larger and more permanent than those found in deeper water and on a clay substrate. Population density at the surface of the substrate varied from a high of 493/M² in June, 1979, to a low of 39/M² in November and December, 1979. There was very little variation in size (shell length) distribution in the population during the year. This lack of size variation may be the result of sampling technique. Most of the clams sampled were between 20-30 mm long,

TABLE 1			
Allele Frequencies at Each Polymorphic Locus			
Allele	Locus		
	GOT	LAP-2	LAP-3
a	0.043	0.043	0.051
b	0.957	0.957	0.949

with very few being less than 10 mm or more than 40 mm. There is evidence that *Corbicula* in the Catawba River have two reproductive periods per year (Hall, personal communication), as has been suggested for all *Corbicula* in the U.S. (Britton et al., 1979).

Seven loci (3 *LAP*, *TP*, 1 *GOT*) were consistently resolved in this study. The three *TP* loci and *LAP-1* were monomorphic. The other loci (*LAP-2*, *LAP-3*, and *GOT*) were polymorphic (Table 1). Percent polymorphism was calculated to be 14.28%; heterozygosity (H) averaged over all loci, (Table 1) was 0.49%. While these estimates are lower than those reported for other invertebrates (Selander and Kaufman, 1973; Powell, 1975), only H is exceptionally low. It is possible that the reduced H is partially a function of a small sample size (n = 142) or the small number of loci sampled (Gorman and Renzi, 1979). A more likely explanation, however, is found in the reproductive biology of the organism.

Corbicula fluminea has, at various times, been considered dioecious, monoecious, and a consecutive protandric hermaphrodite (Britton and morton, 1979). Recently, Kraemer (1979a, 1979b) and Kraemer and Lott (1978) have produced evidence that *C. fluminea* is a simultaneous hermaphrodite and that it may also be self-fertilizing. The pattern of low H and moderate polymorphism is consistent with the suggestion that *C. fluminea* is self-fertilizing. This pattern has recently been found in sphaeriid clams (Hornbach et al., 1980a, 1980b) McLeod et al., 1981 as well as in certain self-fertilizing plants (Rick and Fobes, 1975; McLeod et al., 1979) and animals (Selander and Hudson, 1976). If *C. fluminea* in this country were outbreeding, then with the rapid population growth evidenced, there should be relatively little reduction in H from that of the Asian populations even if the bottleneck were restrictive (Nie et al., 1975). We suggest, therefore, that *Corbicula* in this country are self-fertilizing.

Allelic polymorphisms were not the result of differences between size/age classes, season of the year or reproductive status. There was an indication of a *LAP* locus that was active in the fall about the time the clams appeared to be burrowing into the substrate for the winter months. This locus, however, was only seen in samples collected over a short time period and was present in all specimens regardless of size.

We found no evidence to dispute the contention of Smith et al. (1979) that *Corbicula* in this country originated as a single founder event, and that the subsequent dispersal has been by repeated founder events.

CONCLUSIONS

In summary, using slightly different techniques than those of a previous electrophoretic survey (Smith et al., 1979), we observed some genetic variation in a single population of *Corbicula fluminea*. This variation was organized as very low average heterozygosity and moderate polymorphism. This pattern is consistent with the suggestion that *C.*



Figure 1. Schematic representation of banding patterns observed at GOT and LAP loci. A. GOT locus. B. LAP loci. Each locus is numbered, with the most anodal being 1, the next 2, etc. Letters are allele designations within each locus. The "O" represents the origin.

fluminea is self-fertilizing. We found no differences between organisms of different sizes, or reproductive states. We found no evidence to contradict the assertion that *Corbicula* was introduced to the U.S. once as a founder population and has been spread as a result of a series of founder events.

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THE HISTORIC AND PRESENT DISTRIBUTION OF THE ENDANGERED NAIAD MOLLUSK *LAMPSILIS HIGGINSI* (LEA, 1857)

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ABSTRACT

A continuing search through literature records and museum specimens reveals that *Lampsilis higginsii* was rare, but widely distributed from Mississippi River Mile 283, Louisiana, MO, to River Mile 811, Prescott, WI (528 miles). By 1965 the northern end of the range was reduced by at least 103 miles, and the southern end by 133 miles, a 45% loss of the range. Based on 1977 through 1980 records, the range has decreased to only 251 miles, a loss of 52.5%. Reproduction to assure continuation of the species is questionable even where populations are known to be established. Records indicate that *L. higginsii* was found in at least 10 major tributaries of the Mississippi River, but at present only small populations are known in the Wisconsin River, WI, and in the St. Croix River, WI and MN. Because of the obvious decrease in range, several areas should be designated as critical habitat. Studies of shells found in animal middens will add to the knowledge of the range and of the variable shell characteristics of this naiad. Little is known about the densities of living *L. higginsii* within the present range.

HISTORIC DISTRIBUTION

In a time span of just over 100 years, the naiad mollusk, *Lampsilis higginsii* (Lea, 1857), has been recorded throughout the Upper Mississippi River from Louisiana, MO, River Mile (R.M.) 283 (Utterback, 1915-1916), to Prescott, WI, R.M. 811 (United States National Museum (USNM), Washington, D.C.) (Fig. 1).

A continuing search of published and unpublished records and museum specimens reveals *Lampsilis higginsii* in over 65 locations prior to 1965. This indicates a former widespread distribution throughout 528 miles of the Upper Mississippi River. Only about a dozen sites are represented by museum or literature records of multiple specimens. Although regarded by most authors as a rare species, *L. higginsii* was suitable enough for the pearl button industry (Coker, 1919).

Prior to 1900, *Lampsilis higginsii* was reported by Tryon (1865), Pratt (1876), Witter (1883), and Shimek (1888), and in the University of Minnesota (collected by Holzinger in 1890). From 1900 until 1931 specimens were reported by Baker (1905, 1926, 1928), Geiser (1910), Coker (1919), Grier (1922, 1926), Grier and Mueller (1922-1923),

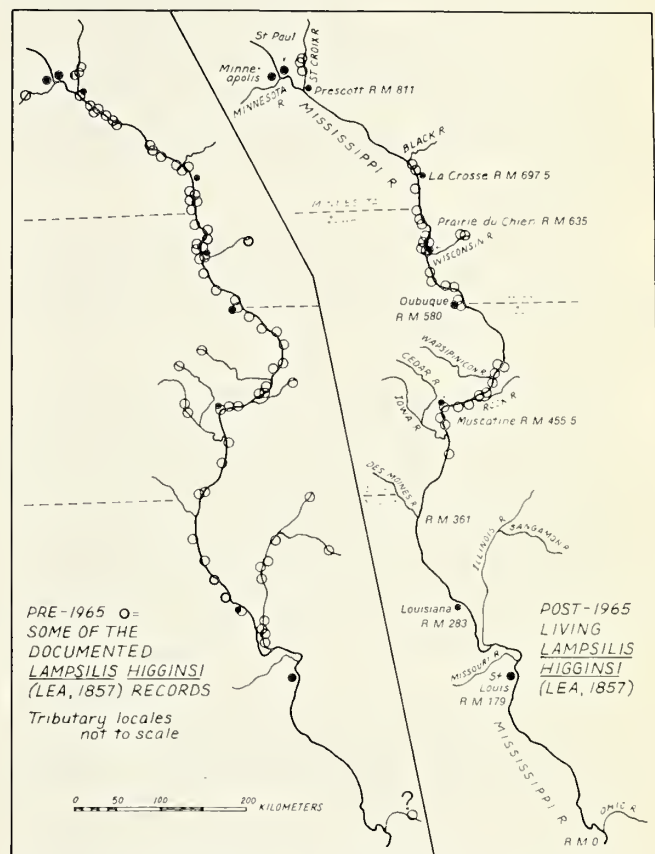


Fig. 1 The distribution of *Lampsilis higginsii* (Lea, 1857) in the Mississippi River and tributaries before and after 1965.

Shimek (1921), and the results of the Ellis survey of 1930 and 1931 were summarized by van der Schalie and van der Schalie (1950). In 1907 Bartsch collected from over 130 sites on the Mississippi and found *L. higginsii* at only 39 sites (USNM). From 1932 until 1965 only Dawley (1947) recorded *L. higginsii*; however, her records were based on older museum records at the University of Minnesota (personal communication, 1975).

Since 1965 living and dead specimens from the Mississippi and

tributaries have been recorded by 1965, 1979, and 1980 Wisconsin Department of Natural Resources surveys (P. Thiel, personal communication, 1980), Havlik (personal collection, 1970 through 1980), Starrett, (1971), Havlik and Stansbery (1977), Fuller (1978), Perry (1979), Mathiak (1979), Nelson and Freitag (1980), and Oblad (1980).

Over 400 dead and 60 living *Lampsilis higginsii* were collected or seen by the author, mainly from the Prairie du Chien, WI, area. Many of the dead specimens are at The Ohio State University Museum of Zoology; most of the live specimens were returned to the river.

MISSISSIPPI TRIBUTARY RECORDS

State of Illinois

Danglade (1914) reported *Lampsilis higginsii* in the Illinois River from Twelve Mile Island to Chillicothe, IL. In 1887 Shimek collected a specimen as far upstream as Morris, IL (USNM), 262 miles from the mouth of the Illinois River. By 1966 only a single sub-fossil valve was found (Starrett, 1971). This species was gradually eliminated by pollution and siltation even before 1930 (Starrett, 1971) and was extirpated from 262 miles of the Illinois River. Baker (1926) was the only one to report *L. higginsii* from the Rock River. The only specimens known from the Sangamon River consist of a growth series of six *L. higginsii* collected in 1886 (Field Museum of Natural History). *L. higginsii* was collected from the Kankakee River (not on map) in eastern Illinois at Lorenzo in 1955 (Illinois State Museum); the status of the species in the Kankakee is unknown today.

State of Iowa

Lampsilis higginsii was reported from the Iowa, Cedar, and Wapsipinicon Rivers in Iowa (Witter, 1883; Shimek, 1888; and Geiser, 1910). Very little has been done on these rivers in recent times and further survey work is recommended (Fuller, personal communication, 1979).

State of Wisconsin

Lampsilis higginsii was reported from the St. Croix River by Dawley (1947) and in 1952 (American Museum of Natural History). The species survives near Hudson, WI, (Fuller, 1978; Science Museum of Minnesota), but the extent of reproduction is unknown (Fuller, personal communication, 1979). Johnson (1980) reported *L. higginsii* from the Wisconsin River, WI (1955), and Mathiak (1979) reported two live specimens at a site 60 miles upstream from the mouth of the Wisconsin River. Bartsch recorded the species from the Black River at La Crosse, WI, in 1907 (USNM); a shell found there in 1978 by the author appeared to have been empty for a long time.

State of Minnesota

One *Lampsilis higginsii* was recorded from the Minnesota River at New Ulm, MN, in 1934 (University of Minnesota; Dawley, 1947). A questionable valve was found near Savage, MN, by the author in 1977. Prospects for any living naiades are unlikely from Savage to the mouth of the Minnesota River, a distance of 15 miles (Fuller, 1978).

Other Records

A record exists of *Lampsilis higginsii* in the Elkhorn River, West Point, NE (USNM), and in the Nemaha River, NE (Aughey, 1877), but the validity is questionable because these specimens were so far out of range.

Lampsilis higginsii has been recorded from several rivers in Arkansas (Wheeler, 1914) and Missouri (Utterback, 1917). Ongoing systematic studies at The Ohio State University Museum of Zoology indicate that specimens from these rivers are a form of the related *L. orbiculata* (Hildreth, 1828) complex (Stansbery, personal communication, 1977); therefore, these site records were not included in Fig. 1.

Lampsilis orbiculata, a more southern species, can usually be distinguished from *L. higginsii* by the lower umbo and lighter periostracum (Wilson and Clark, 1914). Internal anatomical studies show marked differences in the pigmentation and papillae of the incurent aperture as

well as in the structure and pigmentation of the mantle flap (Stansbery, personal communication, 1977). Only a few of the *L. higginsii* shells examined resembled the original description of *L. orbiculata*; however, the question of *L. orbiculata* living in the Mississippi and Illinois Rivers may never be fully answered unless soft parts of atypical *L. higginsii* are available for study.

There is a 1907 record (USNM) of *L. orbiculata* and *L. higginsii* from the Illinois at Hardin, IL (Starrett, 1971). After examining these two specimens, I realized that both were *L. higginsii* and had eventually been catalogued as such at USNM. Similar records of *L. orbiculata* and *L. higginsii* by Witter (1883), Danglade (1914), and Shimek (1921) may have been in error due to the limited concept of these species at that time.

In 1907 a specimen of *L. higginsii* was taken by Bartsch at Hillerman, IL, on the Ohio River (USNM). The specimen has been examined and the identification is correct. This is either the only known record of *L. higginsii* outside its Upper Mississippi River range, or represents a spurious description of specimen or label.

UPPER MISSISSIPPI RIVER RECORDS SINCE 1965

As of 1965 living *Lampsilis higginsii* range had been greatly reduced from Mississippi R.M. 283 to R.M. 416, Oquawka, IL, on the southern end of the river, and from R.M. 811 down to R.M. 708, just above La Crosse, WI, on the northern end, a 45% loss. This left a range of 292 miles (Fig. 1). The records at both ends of this range are, however, 15 years old. Studies from 1977 through 1980 indicate that the northern end of the range is at Brownsville, MN, R.M. 689, and the southern end of the range is at R.M. 437, a further loss of 41 miles. The recent range of *L. higginsii*, as determined by the collection of living specimens, is only 251 miles, a loss of 277 miles of habitable river (52.5%). This range is less than the range formerly known in one tributary, the Illinois River; *L. higginsii* was extirpated from that river in about 40 years. The 1977 through 1980 data reveals no live *L. higginsii* from R.M. 510 to Dubuque, IA, R.M. 581. If the species is not in this area, the range would be reduced to 180 miles of the main stem of the Mississippi, a 66% loss.

Since 1965 *Lampsilis higginsii* has been recorded alive at about 35 general sites, but only a few sites are known to have a number of living specimens. Prime candidates for critical habitat designation are Muscatine, IA; Andalusia Slough, Andalusia, IL; Sylvan Slough, Rock Island, IL; just above Cordova, IL; Dubuque, IA; the area near the confluence of the Turkey River, IA; Prairie du Chien, WI, area; Whiskey Rock area below Lansing, IA; and the St. Croix River at Hudson, WI. These areas and additional areas having live *L. higginsii* should be monitored for adverse environmental changes such as impacts from commercial navigation, barge fleetings, dredging, pollution and commercial clamming (Havlik, 1980).

Little is known of the reproductive status or of live densities of *Lampsilis higginsii*, but studies done by Oblad (1980), Havlik and Marking (1980), and of Pool 10 of the Mississippi River by the Wisconsin Department of Natural Resources (P. Thiel, personal communication, 1980) are a beginning.

SPECIES VARIABILITY

None of the museums visited by the author from 1975 through 1980 has a large series of specimens. Therefore, identification of atypical specimens is somewhat difficult. The large series of specimens, valves and valve fragments recently collected from the Prairie du Chien, WI, area has enabled malacologists to discover the variations that exist in shell characteristics of *Lampsilis higginsii*. Colors of the periostracum range from bright green to olive-brown, reddish-brown, and brown to solid

yellow. The ray patterns may or may not be easily discerned; the intensity and width of the rays differs greatly. The nacre may be solid white or cream; or white or cream with pink or salmon in the beak cavity. Often the entire shell interior is varying shades of salmon or pink.

The shape of the shell may resemble *Obovaria olivaria* (Rafinesque, 1820) or *Actinonaias ligamentina carinata* (Barnes, 1823) as indicated by Baker (1928). Especially elongate specimens may resemble *Lampsilis radiata luteola* (Lamarck, 1819); some young specimens may resemble the generally lighter-weight shell of *L. ventricosa* (Barnes, 1823), and one young specimen's shape resembled *Truncilla donaciformis* (Lea, 1827). I found that a number of *L. higginsii* and *L. orbiculata* specimens collected from an old commercial shell pile, that also contained many other species not indigenous to the Mississippi, could easily be distinguished on the basis of shell characteristics.

The most variable naiad species in the Upper Mississippi River system may be *Lampsilis higginsii*. Studies of shell specimens from animal middens will continue to greatly increase the knowledge of the range and of variation in the shell characteristics of this naiad (Stansbery, personal communication, 1977). *L. higginsii* specimens examined ranged from 22 mm to 114 mm in length.

Lampsilis higginsii appears to be the only naiad found in the Mississippi River and large tributaries that is not found elsewhere in the United States. Perhaps the question as to where this species spent its Pleistocene life will never be answered; however, I suggest that the Driftless Area of southwest Wisconsin, southeast Minnesota, northeast Iowa, and northwest Illinois might have served as a refuge for the species during the last glaciation, which terminated about 10,000 years ago. Archeological specimens of *L. higginsii* from the Driftless Area date back at least 2,000 years (University of Wisconsin, Madison) and this Driftless Area continues to contain the largest known living populations.

CONCLUSIONS

Lampsilis higginsii apparently has never been recorded in the Mississippi River from the junction of the Ohio River, R.M. 0, to the mouth of the Illinois River, R.M. 218. Presumably the 65 mile stretch of the Mississippi above the mouth of the Illinois contained this species, but it was not recorded until R.M. 283, Louisiana, MO. Only five locale records are known between Louisiana, MO, and the mouth of the Des Moines River, R.M. 361. Most of the records found were from the more northern reaches of the Mississippi, above the type locality at Muscatine, IA, R.M. 455.5. This situation still exists in 1980, but the range has been reduced from 528 miles to 251 miles, a 52.5% loss. *L. higginsii* appears to be extirpated from most major tributary rivers and the status is unknown on several other tributaries.

Lampsilis higginsii seems to be suffering the fate of several other North American naiad species; there is genetic diversity, but the range has markedly decreased. If the habitat continues to deteriorate, the existing populations of *L. higginsii* at Prairie du Chien, WI, and other critical areas will undoubtedly decline.

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D.H. Stansbery, The Ohio State University, Columbus; Leif L. Marking, National Fishery Research Laboratory, La Crosse, WI; Samuel L.H. Fuller, Academy of Natural Sciences, Philadelphia, PA; Pamela Thiel, Wisconsin Department of Natural Resources, La Crosse; and Laura Schuh, University of Wisconsin, La Crosse, reviewed the manuscript.

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WHAT DOES "EUTROPHIC" MEAN TO A MOLLUSK?

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ABSTRACT

Many freshwater malacological studies attempt to define the trophic status of the habitat. The terms used to describe trophic status, oligotrophic and eutrophic, have been historically ambiguous and differ in meaning between North American and European usage. In addition, the littoral zone of a lake may differ in nutrient status from the whole lake. Limnologists have recently agreed that whole-lake trophic status is best determined by an annual phosphorus budget, a technique not usually available to malacologists. We recommend that the terms oligotrophic and eutrophic not be casually or generally used for most malacological studies but that the specific microhabitat be defined. For littoral zones we recommend the scheme of Bernatowicz and Zachwieja (1966. Ekol. Pol. A. 14: 519).

Malacologists have long speculated that freshwater molluscan distribution patterns (presence/absence, population density) are influenced by various chemical, physical and biological characteristics of the habitat. Water chemistry, especially calcium hardness, has received the most attention (e.g. Boycott, 1936; Abdel Malek, 1958; Williams, 1970a & 1970b). Other major factors which have been noted as important in influencing molluscan distribution and/or diversity have been vegetation (Baker, 1927; Pip & Stewart, 1976; Lacoursiere et al., 1975.), lake or drainage basin size and/or morphometry (Horst & Costa, 1971; Lassen, 1975; Sepkoski & Rex, 1974), and the trophic status of the habitat (Hubendick, 1958; van Benthem Jutting, 1959; Clarke, 1979a & 1979b). It is in the latter category, trophic status, that confusion and ambiguity arise. It is necessary, therefore, to review the history of the terminology associated with trophic status, point out the differences

between European and North American usages of the terms, and suggest an alternative method which might be used by malacologists to standardize habitat description. Standardizations must be made if conclusions on comparative ecological molluscan studies are to be valid.

The classification of lakes as oligotrophic or eutrophic began in northern Europe and Scandinavia where almost sterile, soft-water lakes are found on the Fenno-Scandian shield (similar to the Canadian shield), and fertile, hard-water lakes are found on the Cretaceous lowlands. Hard-water lakes were coincident with eutrophy and soft-water lakes with oligotrophy. No sooner was the classification articulated, than exceptions began to be found. Extremely hard-water alkaline lakes were found in northern Germany. These lakes had as limited a species diversity and internal metabolism as did the soft-water shield lakes. Alpine lakes were found to be variable and ambiguous with respect to chemical, biological, and morphometric trophic status (see Hutchinson, 1969, and Cole, 1979, for a history of the terms). However, rather than discouraging the idea of lake classification, over the years these problems stimulated an enormous excess of definitions competing for the terms oligotrophic and eutrophic. Some limnologists prefer not to use the terms at all (Moss, 1980).

Two broad categories can be established for the criteria used to distinguish oligotrophic and eutrophic: metabolic and non-metabolic. Metabolic criteria would include any reasonably direct measure of lake metabolic intensity, such as areal hypolimnetic oxygen demand, nutrient concentrations, chlorophyll concentrations, and photosynthetic uptake of ^{14}C . non-metabolic criteria would include indicator species, species diversity, community structure, and community classification.

About a decade ago, limnologists had to find a majority position on lake classification in order to be able to determine if pollution were occurring. At that time a majority of eminent limnologists found that they could agree that the annual phosphorus budget for a lake was the best criterion available for measuring eutrophication. (See Vallentyne, 1974, for a discussion on the biological role of phosphorus). Defining oligo-

trophic and eutrophic lakes in terms of phosphorus available for growth not only makes sense in itself, it can also be correlated with most other criteria that have been used for classifying lakes.

Malacologists, like limnologists, have used various criteria in defining eutrophy. Some authors use the terms without defining the specific criteria used (Clarke, 1979a & 1979b; Harman & Forney, 1970; Hermann & Harman, 1975). European malacologists and limnologists define eutrophic habitats as being rich in electrolytes (e.g. Hubendick, 1958; van Benthem Jutting, 1959; Lassen, 1975). Comparing North American eutrophic to European eutrophic is comparing nutrient-rich habitats to hard water habitats. McMahon (1975), Hunter (1975) and Eversole (1978) have defined eutrophy on a comparative basis by measuring the quantity and quality of *Aufwuchs* (methods described in McMahon et al., 1974). Unfortunately, the method necessitates long term submersion of artificial substrates to collect the *Aufwuchs* biomass. The problems, however, are even more complex than this.

As the concepts of oligotrophy and eutrophy have become more restricted in modern limnological usage, lakes, themselves, have become more difficult to classify. There are many new kinds of lakes as the result of reservoir building, improvements in navigation, hydroelectric diversions, storm water storage, etc. These lakes are frequently out of context with respect to the biological province or geological lake district in which they are found. Their morphometric development may be immature and radical relative to neighboring lakes. Their watershed to lake area ratio may be extraordinary, and the sources of their water may be highly modified (Wetzel, 1975). Finally, cultural input of phosphorus, nitrogen, acid rain, and toxic materials may make a profound change in the nature of even a so-called natural lake.

The littoral zone, where mollusks live, may or may not reflect the trophic status of the lake as a whole. The littoral may behave as a living filter which isolates the deeper waters of a lake from watershed inputs. Water from a warm fertile inlet might stay in the shallows causing a thermal "littoral block", or a clear cold-water inlet stream might flow across the littoral slope and cause an otherwise eutrophic lake to harbor "oligotrophic" species. Therefore, malacologists probably should classify littoral zones only and not attempt inferences about whole lake metabolism.

An excellent system of littoral zone classification exists (Bernatowicz & Zachwieja, 1966), and has been well received among limnologists (Hutchinson, 1975). Bernatowicz & Zachwieja recognize three basic types of littoral:

- (1) Litholittoral: rocks, boulders, gravel - no sand or silt.
- (2) Psammolittoral: sand, some macrophytes.
- (3) Phytolittoral: covered by plants or results of their decay. Five phytolittoral subtypes are recognized: large-lake, small-lake, pond, marsh, and atrophic. Details are discussed in Hutchinson (1975, p. 453-460). Within these three types, very specific descriptions may be based upon zonation of aquatic macrophyte growth forms, species, and abundance, upon mechanical analyses of the sediments, and upon organic weight of the sediments.

We recommend that the terms eutrophic and oligotrophic not be generally or loosely used in molluscan habitat studies but that the microhabitat (e.g. the littoral zone) be described independently of the whole lake. The scheme of Bernatowicz & Zachwieja (1966) should be acceptable to both limnologists and malacologists.

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DECLINE OF THE ASIATIC CLAM, *CORBICULA FLUMINEA*, IN THE LOWER TENNESSEE AND CUMBERLAND RIVERS

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ABSTRACT

During the 10 years prior to 1977, the Asiatic clam in the lower Tennessee River provided a substantial resource to the bait dealers and commercial fishermen using clams for fishbait. In August 1977 there was a massive and unexplained mortality of the clams in the lower Tennessee and Cumberland Rivers below Kentucky and Barkley Dams. By the end of that summer, bait dealers reported that they could no longer find the clams.

The present study has confirmed the absence of adult, commercially valuable clams in the rivers. Only small, younger than 1 year old clams have been found in benthic samples and fish stomachs from below Kentucky and Barkley dams to the Ohio River. This represents a significant loss to both the fishermen and the natural fish community. *Corbicula* less than 1 year old occurred in 68% of the samples from the Tennessee River and 36% of samples from the Cumberland River. Densities in the Tennessee River ranged from 10 to 389/m². Mean monthly shell lengths and clam densities in both rivers indicate that good recruitment occurs in the summer. The populations have started to recover each fall since 1978, but during the following summers the 1 year old clams do not

survive. The only reproducing populations of large adult clams were found in Kentucky Lake at mile 61 and in Barkley Lake at miles 66-70.

INTRODUCTION

Since it was first discovered in North America in 1938 (Burch, 1944), the Asiatic clam, *Corbicula fluminea* (Muller, 1774), has invaded every major river system in the United States excluding the Great Lakes drainage, northern Atlantic states, and extreme northwest. Its spread has been well documented (Sinclair and Ingram, 1961; Sinclair and Isom, 1963; Sickel, 1973; Fuller and Powell, 1973). In many cases the clam has become a nuisance since it fouls municipal and industrial water systems, interferes with sand and gravel industries, and is detrimental to native mussels (Sinclair and Isom, 1963; Gardner et al., 1976). On the positive side, *Corbicula* has provided a new food resource for fish and wildlife, and it is being used for fish bait (Sickel et al., 1980). In the future, *Corbicula* may provide an important protein and calcium supplement in animal feeds and may serve as a food resource for man in North America as it does in Asia (Miller and McClure, 1931).

The Asiatic clam in North America has been referred to by various authors as *Corbicula fluminea*, *C. leana*, *C. fluminalis*, *C. manilensis*, and even as *C. sinensis*. The confused taxonomy is due to the highly polymorphic characteristics of the genus in general and to the lack of knowledge regarding the origin of the North American populations. Over a hundred species of *Corbicula* have been described from the Orient (Prasad, 1929); however, most of these should be synonymised under a few names, *Corbicula fluminea* being the most common species (Morton, 1979). Recent biochemical studies of 18 enzyme systems using starch gel electrophoresis showed no genetic variability within or between five United States populations of *Corbicula* from California, Texas,

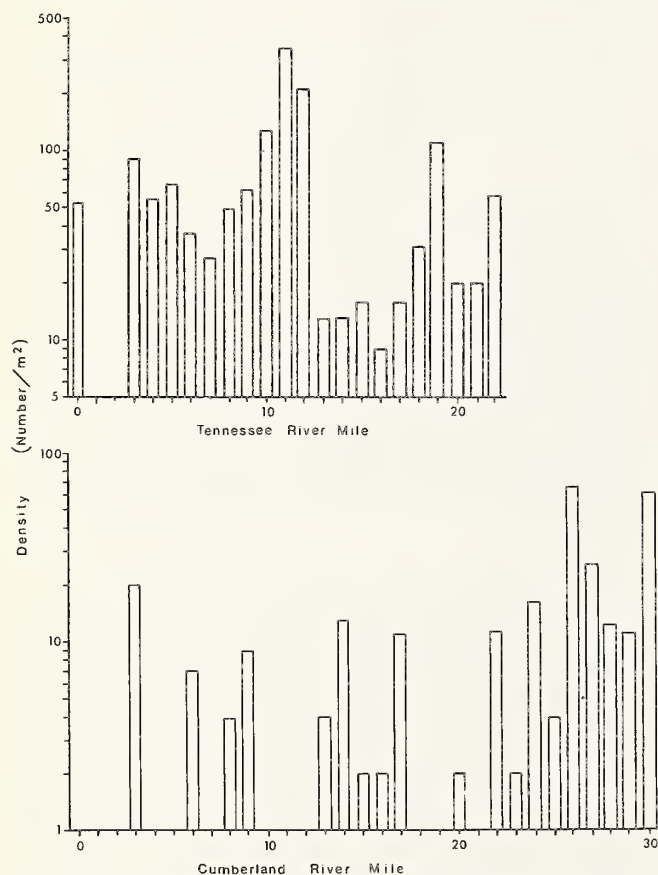


Figure 1. Density of *Corbicula* at collection sites in the Tennessee and Cumberland Rivers from October 1978 to August 1980.

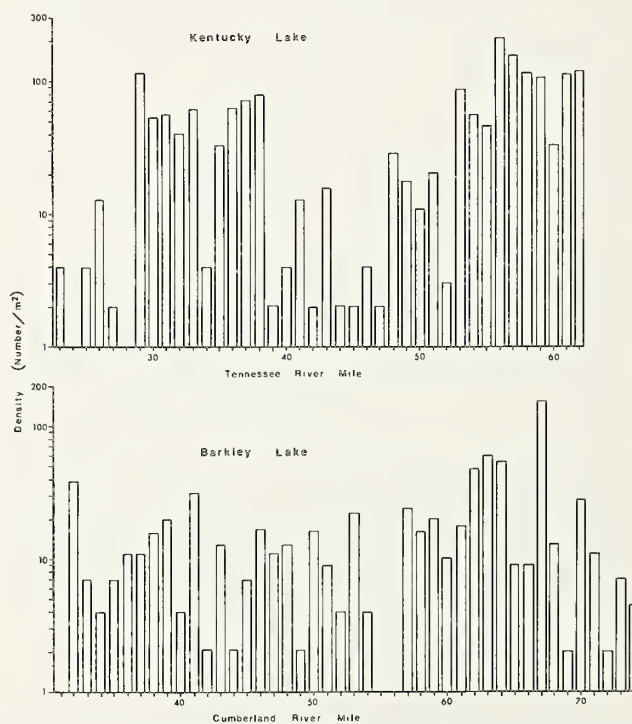


Figure 2. Density of *Corbicula* at collection sites in Kentucky and Barkley Lakes from October 1978 to August 1980.

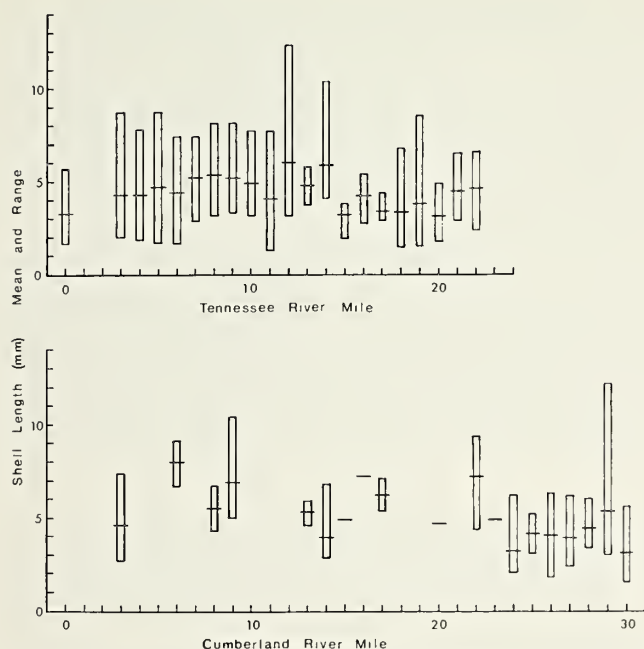


Figure 3. Mean (—) and range of shell lengths of *Corbicula* at collection sites in the Tennessee and Cumberland Rivers from October 1978 to August 1980.

Arkansas, Tennessee, and South Carolina (Smith et al., 1979). Comparing the United States samples with samples from Japan and Southeast Asia which did have genetic variability, Smith et al. (1979) concluded that the U.S. populations were most closely related to Hong Kong and Philippine populations. They postulated that the loss of genetic variability was a result of the founder principle. Perhaps the present North American populations are derived from only a few individuals which were successful immigrants, and through inbreeding and genetic drift the original population became homozygous for the 18 enzymes examined. Morton (1979) believes all U.S. *Corbicula* to be *Corbicula fluminea* (Muller, 1774).

Corbicula was first noticed in the Mississippi River System in 1957 when clogging problems occurred at the TVA Shawnee Power Plant on the Ohio River at Paducah, Kentucky near the mouth of the Tennessee River (Sinclair and Isom, 1963). Two years later it was found 206 miles upstream in the Tennessee River in the tailwaters of Pickwick Dam (Sinclair and Ingram, 1961).

During the ten years prior to 1977, *Corbicula* was harvested from the lower Tennessee River in western Kentucky and sold for fish bait. Commercial collectors were receiving 2¢ per live clam and wholesale bait dealers were selling the fresh meat for 4¢ per clam. Retail dealers were receiving 8-9¢ per clam. No accurate estimate of the value of this fishery industry has been made, but two dealers indicated they could sell all the clams they could get. Collectors once obtained most of their *Corbicula* from beds in the Tennessee River downstream from Calvert City, Kentucky (Sickel et al., 1980). Williams (1969) reported catching 2,071 large *Corbicula* on mussel trails while sampling mussel beds in the Tennessee River below Kentucky Dam. This number was 40.5% of the total bivalve catch. Dredge samples collected by Williams (1969) contained 99.4% *Corbicula* with a density of from 20 to 1372/m². Commercial fishermen who harvested *Corbicula* reported that there was a massive mortality of the clams in August, 1977. Since that time there has not been an appreciable harvest of large *Corbicula* from the lower Tennessee River.



Figure 4. Mean (—) and range of shell lengths of *Corbicula* at collection sites in Barkley and Kentucky Lakes from October 1978 to August 1980.

Mass mortalities of unknown cause have been reported at a number of locations on the Tennessee, Cumberland, and Ohio Rivers. During the week of April 17, 1961, large numbers of dead clams washed ashore at Wolf Island (Tennessee River Mile 192.5) and also on the Cumberland River at mile 100 (Sinclair and Isom, 1963). On August 30 and 31, 1962, on the Tennessee River, the traveling screens at the Chattanooga Water Treatment Plant became clogged with clam bodies. When the clams die the bodies begin to decompose, pop from the shells, and float to the surface (Sinclair and Isom, 1963). Horning and Keup (1964) reported a decline of *Corbicula* from 27 per square foot in 1962 to 1 per square foot in 1963 in the Ohio River at Cincinnati. They speculated that the cold winter with the Ohio River being frozen over for seven days to have caused a winter kill. Bickel (1966) reported annual spring mortalities of all age classes of *Corbicula* in the Ohio River at Louisville, Kentucky, during March. He attributed those die-offs to high suspended sediment loads accompanying spring floods.

Near anoxic conditions were reported in the deep channels and large embayments of both Kentucky and Barkley Lakes in the summer of 1977 (Johnson and Sickel, 1979). This led to the death or migration of many benthic invertebrates. Whether or not the anaerobic conditions in the two lakes contributed to the mortality below the dams is unknown.

"Floaters" were observed in Barkley Lake at Cumberland River mile 67 on August 18, 1979. These were dead *Corbicula*, 35-40 mm in length, which had begun to decompose with the shell tightly closed. Enough gas had been produced to cause floatation.

The present project was intended to evaluate the commercial potential of *Corbicula* in the lower Tennessee and Cumberland Rivers including the Kentucky portions of Kentucky and Barkley Lakes and to determine if populations were recovering from the August 1977 mortality.

MATERIALS AND METHODS

Sampling for the Asiatic clam, *Corbicula fluminea*, in the lower Tennessee and Cumberland Rivers from the Ohio River to Kentucky and Barkley Dams and in the Kentucky portions of Kentucky and Barkley Lakes was initiated in October 1978. Collections were made with a 0.05 m² Ponar grab from transects located at 1 mile intervals. Three grab samples each from near the east and west banks and mid channel were analyzed from each transect. Sand and gravel bars were also examined. Commercial bait dealers were interviewed for information regarding the locations of old clam beds prior to the die-off, and these sites were examined extensively. Grab samples were washed through a series of screens of decreasing mesh size with the smallest being 0.5 mm. Fish stomachs were examined for clams also.

RESULTS

During the two years of sampling, October 1, 1978, to August 1, 1980, no adult *Corbicula* were found in the lower Tennessee or Cumberland Rivers from the Ohio River to Kentucky and Barkley Dams. Many large, dead shells were collected on the banks of the Tennessee River indicating that they were once abundant. Some of these shells measured 50-60 mm in length. The clam mortality apparently affected all adult *Corbicula*.

The density of young clams in the lower Tennessee and Cumberland Rivers (Fig. 1) indicates that good recruitment of larvae has occurred since the mortality. Larvae probably came from Kentucky and Barkley Lakes where reproducing populations were found. In the lower Tennessee River, clam densities ranged from 10 to over 300/m², but most of these clams were from 3 to 6 mm in length (Fig. 3) with only a small percentage reaching 12 mm (1 year old). If these young clams survived to maturity (1 year) and harvestable size (3-4 years), the commercial clam fishery would return in a few years. However, from June to August 1979 and again in 1980, clams 12 mm and larger in size disappeared from the rivers. Whatever caused the initial mortality in 1977 still appears to be affecting the *Corbicula* as they reach maturity.

Corbicula younger than 1 year old occurred in 68% of the grab samples from the Tennessee River and 36% of those from the Cumberland River. The highest densities were found in areas of low siltation where the substrate consisted of coarse sand, gravel or pebbles. Densities generally increased downstream from Kentucky Dam with a maximum of 380/m² occurring at mile 11 (Fig. 1). No clams were found at miles 1 and 2 where the water currents had scoured the bottom. In the Cumberland River, clam densities decreased downstream from Barkley Dam (Fig. 1). More sites located downstream were without clams because an increasing number of transects occurred over a substrate consisting of bedrock. Only young clams were found in fish stomachs (Sickel et al., 1980).

Clam densities in Kentucky and Barkley Lakes reached a maximum of 220 and 160/m² respectively (Fig. 2). As also occurred in the rivers, most of the clams in the lakes were under 1 year old with shell lengths less than 12 mm (Fig. 4). However, reproducing populations with large adults were found in both lakes near the Kentucky-Tennessee state line. In Kentucky Lake only a few clams over 35 mm in length were found at river mile 61. In Barkley Lake a dense population of clams reaching 50 mm in length occurred between miles 66 and 70.

CONCLUSIONS

A massive mortality of *Corbicula fluminea* occurred in the lower Tennessee River in August 1977. Benthic sampling in the Tennessee and Cumberland Rivers from the Ohio River to Kentucky and Barkley Dams failed to locate any adult, commercially valuable, *Corbicula*. Large num-

bers of young clams less than 1 year old were found throughout the rivers, but they did not survive beyond a year indicating that the populations are not recovering from the 1977 die-off. The cause of the mortality is unknown. The only reproducing populations were found upstream from mile 60 in Kentucky Lake and mile 65 in Barkley Lake. Perhaps the greater current velocity further upstream in the reservoirs enhances the survival of the clams. The recurrent annual mortality of *Corbicula* is of sufficient economic and ecological significance that an intensive effort should be expended to discover its causes.

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ECOLOGICAL NOTES ON TWO SYMPATRIC,
CONCHOLOGICALLY CONVERGENT POLYGYRID
LAND SNAILS IN OHIO.

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ABSTRACT

From March to July, 1979, a standard course in a deciduous woodland in S.E. Ohio was walked on 18 occasions, at least one week apart, between 12 and 2 A.M. A total of 72 *Triodopsis albolabris* and *Mesodon thyroideus* were measured, mapped, and marked. There was no difference in the substrata upon which the two species occurred, but adult *T. albolabris* showed more clumped dispersion, proximity to larger rocks, and more restricted weather requirements for activity than adult *M. thyroideus*. It was concluded that *M. thyroideus* occupies a broader niche than *T. albolabris*, that may preclude competition between these sympatric, convergent species.

Pilsbry (1940) called attention to the many cases of close convergence between species of *Mesodon* and *Triodopsis*, polygyrid genera of separate evolutionary histories as evidenced by their genitalia. Two or more such species are sometimes sympatric or at least microallopatric (Solem, 1976). The purpose of this study was to determine whether detectable niche differences that might enable them to avoid competition occur between of one such convergent pair of species.

Triodopsis albolabris albolabris and *Mesodon thyroideus* have overlapping ranges covering most of the northeastern quarter of the United States (Pilsbry, 1940; Vagvolgyi, 1968; McCracken and Brussard, 1980). The shells of these two species are very similar in overall shape and in microstructure. Although the shell of *Mesodon thyroideus* is generally smaller, there is some overlap in size. The remaining diagnostic distinctions are that adult *M. thyroideus* has an umbilicus only half covered by the reflected apertural lip and usually has a small parietal barrier (Pilsbry, 1940 whereas *T. albolabris* does not. Both species are nocturnal. *T. albolabris* has shown peak activity between midnight and 3 a.m.

(Henne, 1963), and *M. thyroideus* has shown activity from dusk to dawn (Blinn, 1963).

METHODS AND MATERIALS

A course (map, Fig. 1) was selected along a hillside in Strouds Run State Park, Athens County, Ohio to encompass a variety of habitats: grassy slope, wooded slope, dirt trail, decayed logs, talus piles, and rock bluffs. The general habitat is secondary oak-ironwood-tulip forest with numerous maple saplings, characterized by occasional sandstone blocks and talus. The course went up the hillside, then turned to join a foot trail which followed a contour line. Several excursions up and down the slope were made to likely-looking habitats. When the foot trail went downhill, the course turned to continue on the same contour level. Between 23 March and 28 July 1979, I walked the course approximately weekly, generally between midnight and 2 a.m. (intervals were longer between the last few walks). A Coleman lantern was used and, for each snail encountered, the greatest shell diameter, shell height, number of whorls, the distance to several landmarks (trees, rocks, etc.) and the type of substratum were recorded. I then numbered the shell on the dorsal and ventral and left the snail in its original position.

To get an unbiased estimate of dispersion, I gave a tracing of the field of view from Fig. 1 to an assistant with instructions to divide it into short intervals of equal area. The result was 22 consecutive plots. Using the log-transformed numbers of each species per plot, I used a runs test above and below the mean (Sokal and Rohlf, 1969) to test the null hypothesis of random dispersion along the walked course.

To test for differences between the species (and their juveniles) in their dispersion relative to potential shelter, I made the following four measurements from the map (Fig. 1) for each snail: distance to nearest tree, size of nearest tree, distance to nearest rock, and size of nearest rock. Differences among species and juveniles were tested by Kruskal-Wallis nonparametric analysis of variance (Sokal and Rohlf, 1969).

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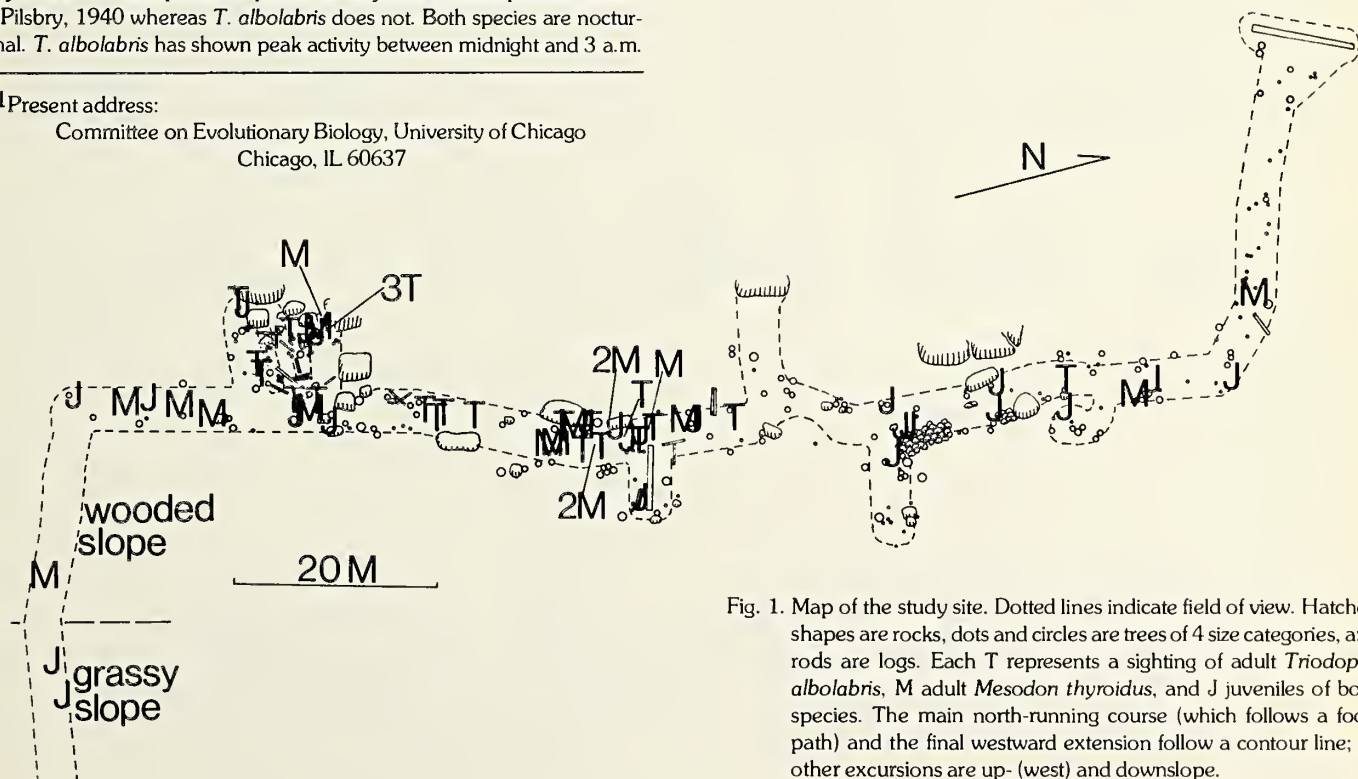


Fig. 1. Map of the study site. Dotted lines indicate field of view. Hatched shapes are rocks, dots and circles are trees of 4 size categories, and rods are logs. Each T represents a sighting of adult *Triodopsis albolabris*, M adult *Mesodon thyroideus*, and J juveniles of both species. The main north-running course (which follows a foot-path) and the final westward extension follow a contour line; all other excursions are up- (west) and downslope.

An RxC test of independence using the G-test (Sokal and Rohlf, 1969) was used to test the null hypothesis that substrate was independent of species (*T. albolabris* vs. *M. thyroideus* vs. juveniles).

Daily weather data for the study period were obtained from the Geography Department of Ohio University, which records data approximately five miles from my study site. Canonical correlation analysis (Dixon and Brown, 1977) was performed between a set of variables derived from the weather data on the one hand and the set of snail species counts for 18 nights on the other hand.

RESULTS

There were a total of 72 sightings of the two species, including 7 recaptures. Although *T. albolabris* adults were larger than *M. thyroideus* adults (t-test, unequal variances, comparing mean diameters, $p < 0.0001$), there was some overlap. Adult shell diameter ranged from 23.5 to 29.6 mm for *T. albolabris* ($n=20$, $\bar{y}=27.2$, $sd=1.8$) and from 21.9 to 25.4 mm for *M. thyroideus* ($n=20$, $\bar{y}=23.5$, $sd=0.9$). The plots of both shell height and number of whorls on shell diameter indicate markedly similar regression lines for both species, as well as for the juveniles (Figs. 2 and 3). Thus there was no perceptible difference between juveniles of the two species. Since shell microstructure is also nearly identical for the two species (Pilsbry, 1940), juveniles could not be identified to species until they developed the diagnostic lip and barrier characters of maturity. For this reason, juveniles of both species were lumped as a single separate category.

Other species encountered during the 18 walks were *Triodopsis tridentata* (2), *Mesomphix inornatus* (20, including 1 recapture), *Haplotrema concavum* (4), *Ventridens* sp. (2), and the slug *Philomycus carolinianus* (42). *Mesomphix* was generally encountered on very damp nights and in small, relatively wet depressions. *Philomycus* was mostly found above ground on the trunks of dead ironwoods and occasionally on exposed rock outcrops.

Only *T. albolabris* showed significantly clumped dispersion (runs test, $p < 0.05$) (Table 1). *M. thyroideus* and juveniles showed no significant departure from randomness. Of four measures concerned with size and proximity of trees and rocks, the species differed significantly only for the size of the nearest rock (Kruskal-Wallis test, $p = 0.01$) (Table 2): generally, *T. albolabris* was near large rocks, juveniles were near small rocks, and *M.*

Table 1. Runs test (above and below mean) for randomness of dispersion.

	NUMBER ABOVE	NUMBER BELOW	NUMBER OF RUNS	SIGNIFICANCE LEVEL
<i>Mesodon thyroideus</i>	10	12	13	n.s.
<i>Triodopsis albolabris</i>	8	14	5	$p < 0.05$
Juveniles (both species)	14	8	8	n.s.
All the above	14	8	7	n.s.

thyroideus was intermediate. Differences in size-of-the-nearest-tree approached significance ($p < 0.10$) with *M. thyroideus* being the species nearer to the largest trees.

The two species and their juveniles did not significantly differ in the substrates upon which they were found (RxC test of independence, $0.10 < p < 0.25$). Pooling the data for the 53 sightings for which substrate was recorded, 60% were on leaf litter, 25% on bare soil, 8% on rocks, and 8% on live plants.

Rainfall and temperature data plotted against number of snails sighted (Fig. 4) suggest that greatest total numbers appeared whenever mean temperature rose following a brief period of rain, but the data are too scarce to be conclusive. Canonical correlation between the set of snail sightings and the set of weather variables yielded three canonical variates (CV's) with canonical correlations of 0.96, 0.83 and 0.54 (Table 3). Only the first of these approached significance, but, according to Pimentel (1979), a non-significant CV is still of value in detecting trends in the data and so will be interpreted. CV1 ($p = .07$) had strong positive loadings on *T. albolabris*, all temperature variables, and amount of rain in past 10 days, and it had a strong negative loading on the number of days since the last 3-day rain. CV2 ($p = .65$), with a strong positive loading on *M. thyroideus*, had weak positive loadings on most temperature variables and on the number of days since the last 3-day rain. CV3, ($p = .90$) with a strong positive loading on juveniles (and some strong contamination from *T. albolabris*) showed strong negative loadings on all temperature variables and a weak negative loading on the number of days since the last half-inch of rain. In addition, all three CV's showed weak negative loadings on the daily rainfall. Interpreting the CV's, *T. albolabris* activity, the most predictable, was associated with warm temperatures and recent rain (within the past 10 days). *M. thyroideus*, less predictable, was some-

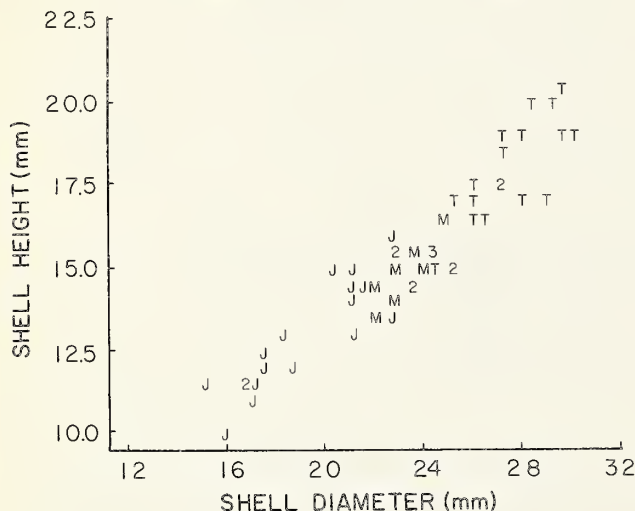


Fig. 2. Shell height vs. shell diameter for all measured snails. T = adult *Triodopsis albolabris*, M = adult *Mesodon thyroideus*, and J = juveniles of both species.

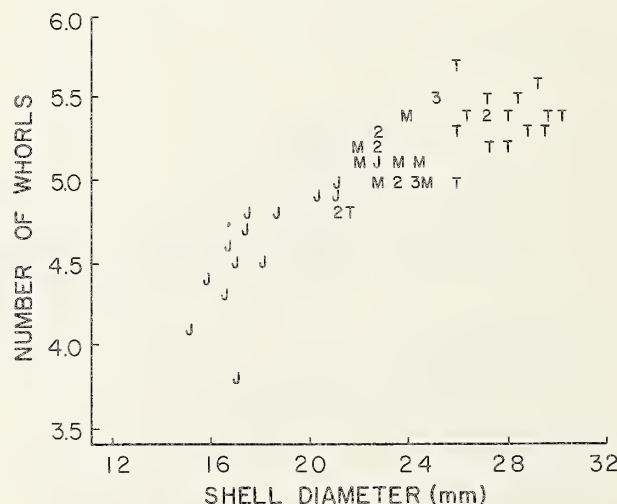


Fig. 3. Number of shell whorls vs. shell diameter for all measured snails. Letters as in Fig. 2.

Table 2. Kruskal-Wallis tests for differences in ecological parameters.

	SUM OF RANKS			H/D	SIGNIFICANCE LEVEL
	<i>M. THYROIDUS</i>	<i>T. ALBOLABRIS</i>	JUVENILES		
DISTANCE TO NEAREST TREE	713.5	822.5	746.0	0.5667	n.s.
SIZE OF NEAREST TREE	876.5	678.5	595.5	4.5844	$p \approx 0.10$
DISTANCE TO NEAREST ROCK	742.0	760.5	573.0	~ 0.0	n.s.
SIZE OF NEAREST ROCK	761.5	936.5	353.0	9.5508	$p < 0.01$

what associated with warm temperatures, and was less dependent on recent rainfall. Juveniles could tentatively be said to be correlated with cooler temperatures and recent heavy rainfall.

DISCUSSION AND CONCLUSIONS

As indicated by the low recapture rate, only a small percentage of the total snails present were sighted. One of the advantages of working with convergent species in this case was that both species were equally visible when present on the surface. Small sample sizes were a drawback to this study, but were unavoidable due to low densities typical of sandstone regions (Baker, 1939).

Separation of adults and juveniles for ecological comparisons is worthwhile. Blinn (1963), for example, found distinct differences in climbing behavior and activity between adult and juvenile *M. thyroideus* in an oak-maple forest in Cook County, Illinois. This study suggests that juveniles may have different weather requirements for activity than adults.

Table 3. Loadings on canonical variates comparing numbers of snails sighted with weather variables.

SNAILS	CANONICAL VARIATES		
	1	2	3
<i>Mesodon thyroideus</i>	-0.018	0.930	0.367
<i>Triodopsis albolabris</i>	0.626	0.238	0.742
Juveniles (both species)	-0.161	-0.100	0.982

WEATHER			
Maximum temperature	0.674	0.351	-0.400
Minimum temperature	0.516	0.158	-0.543
Mean temperature	0.631	0.271	-0.513
10-day maximum temperature	0.521	0.301	-0.419
10-day mean temperature	0.546	0.019	-0.401
Rain during day	-0.109	-0.197	-0.241
Amt. rain in past 10 days	0.515	0.088	0.051
No. days of last 5 with rain	0.362	-0.101	0.002
No. days since last $\frac{1}{2}$ " rain	-0.037	-0.131	-0.218
No. days since last 3-day rain	-0.486	0.246	-0.145

The difference between species with regard to dispersion (Table 1) is a relative one only. The indication is merely that *T. albolabris* are more clumped than *M. thyroideus* or juveniles. This contagious dispersion is probably the result of habitat preference.

M. thyroideus was only rarely (one of 18) seen climbing on trees and vegetation. This was in contrast to Blinn's (1963) finding in an Illinois population that "an outstanding behavioral characteristic of *M.*

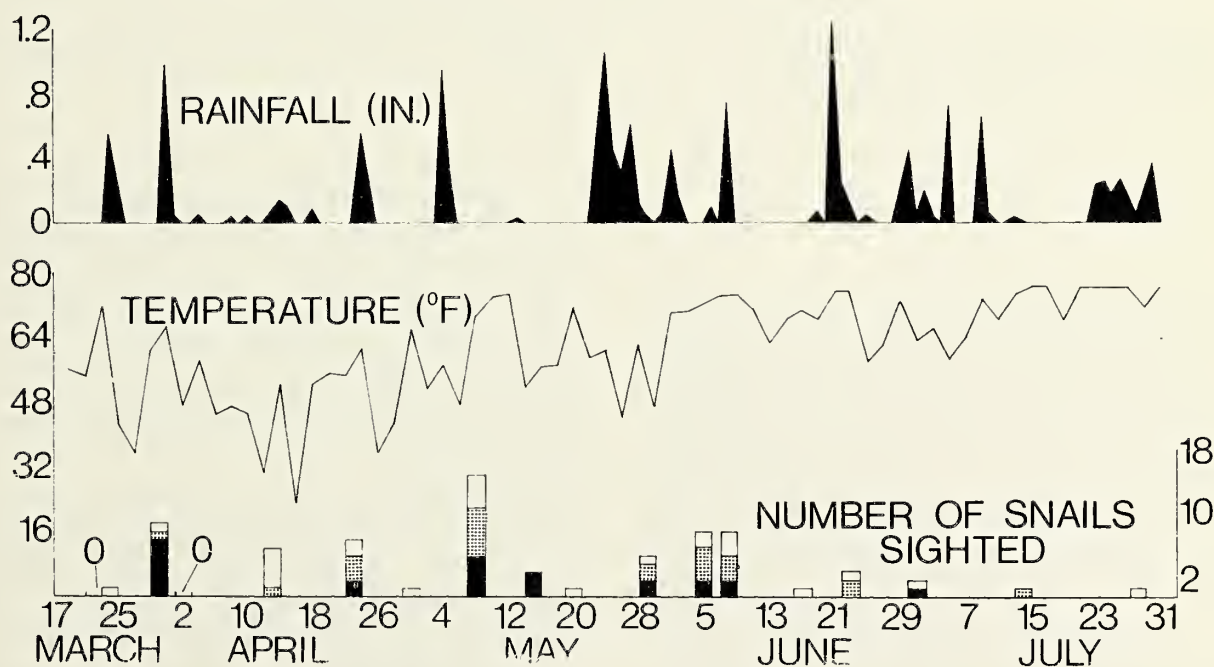


Fig. 4. Number of snail sightings for each of 18 samples, plotted with weather data. Stippled bars represent adult *Triodopsis albolabris*,

black adult *Mesodon thyroideus*, and white juveniles of both species.

thyroidus, apparently a normal facet of its nocturnal activity, is tree climbing." He found, for example, that on 3 occasions in his enclosures, 40, 75 and 62% of the active snails were climbing. Whether this contrast indicates a difference in habitat or a genetic difference in behavior between two populations would be worth investigating.

Canonical correlation proved an effective tool for exploring the relationship between weather conditions and snail activity. Despite small sample sizes, the results strongly suggest that *T. albolabris* was more predictable in its requirements for surface activity, and that these requirements were warm temperatures and recent, but not current, rainfall. These conclusions are consistent with Henne's (1963) report that *T. albolabris* kept under natural light conditions in the laboratory showed lowest average daily movement at 10°C, and intermediate at 30°C. That *M. thyroidus* tolerates relatively dry conditions was supported by the findings of Blinn (1963) for the same species in Illinois. Blinn also stated that activity of *M. thyroidus* seemed inhibited during rainfall, as was suggested by this study.

Randolph (1973) compared the ecologies of two unrelated species of snails in Texas: *Mesodon roemeri* living in woodlands, and *Bulimulus dealbatus* living in grassland and woodland. The latter had a broader niche, and also had a higher intrinsic rate of natural increase, shorter lifespan, smaller clutch size, shorter developmental time, more general behavior relative to its habitat, more general food requirements, and smaller maintained biomass. It can be predicted that in the species pair *Triodopsis albolabris* and *Mesodon thyroidus*, a similar but less extreme ecological dichotomy would be found, with *M. thyroidus* exhibiting the adaptations associated with a broader niche relative to *T. albolabris*.

It remains to be determined how the minor conchological differences between *Triodopsis albolabris* and *Mesodon thyroidus* relate to their ecological differences. In addition, comparative ecological studies of conchologically even more closely convergent species pairs, both in sympatry and allopatry, would be of value.

A QUANTITATIVE ANALYSIS OF NAIAD MOLLUSKS FROM THE PRAIRIE DU CHIEN, WISCONSIN DREDGE MATERIAL SITE ON THE MISSISSIPPI RIVER

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ABSTRACT

The Prairie du Chien dredge material site contains about 100,000 cubic meters of material dredged from the East Channel of the Mississippi River in 1976. Previous studies in that area suggested a rich molluscan fauna, but most studies were only qualitative or simply observations. Our study of this material was designed to determine the density and diversity of molluscan fauna, to assess changes in the fauna, to identify endemic species previously unreported, and to evaluate the status of the endangered *Lampsilis higginsii*. Ten cubic meters of dredge material were sieved to recover shells. Molluscan fauna at the site contained 38 species of naiades and up to 1,737 identifiable valves per cubic meter. The endangered *L. higginsii* ranked 18th in occurrence, accounted for only 0.52% of the identifiable shells, and averaged about three valves per cubic meter. From a total of 813 kg of naiades and gastropods, 6,339 naiad valves were identified. Five naiad species were collected at the site for the first time, and *Epioblasma triquetra* had not been reported previously in the Prairie du Chien area. Although the molluscan fauna has

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changed, the East Channel at Prairie du Chien is obviously suitable for *L. higginsii*.

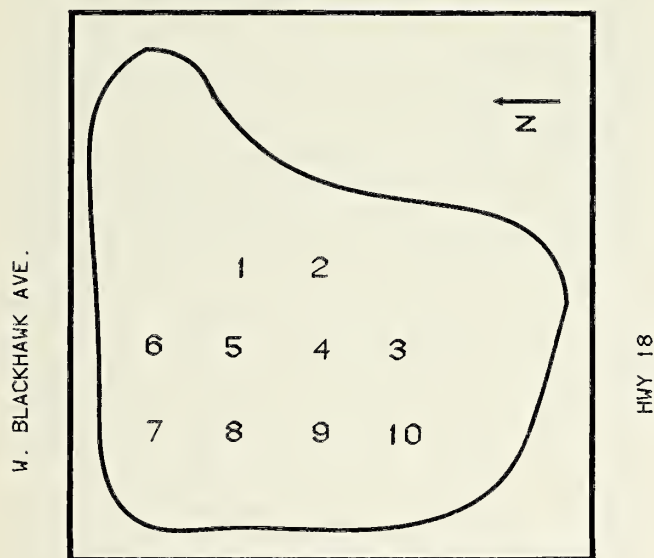
INTRODUCTION

Havlik and Stansbery (1977) reported 33 species of naiad mollusks at the Prairie du Chien, Wisconsin dredge material site. Although their study was qualitative, they reported 14 valves of *Lampsilis higginsii*, an endangered species. The presence of large numbers of *L. higginsii* and other mollusk shells verified an abundant fauna in the Prairie du Chien area, but comparisons with past records suggested a significant change in species composition, abundance, and distribution (Baker, 1905; Shimek, 1921; Baker, 1928; van der Schalie and van der Schalie, 1950; Havlik, 1980a). Since the 1977 study, 88 discrete specimens or fragments of *L. higginsii* have been discovered on the surface of the dredge material. Apparently, additional valves continue to be exposed by erosion processes.

The abundance of shells in the dredge material and past records of mollusks in the area suggested that the site was an excellent location to do a quantitative sampling of the molluscan fauna. Quantitative sampling for naiad mollusks in dredge materials has never been reported, but such information would be useful for evaluating population densities and diversities. The presence of *L. higginsii* suggested that habitat needed for their survival was available.

The objectives of this study were to quantitatively sample the Prairie du Chien dredge material area in order to determine the density and

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EAST CHANNEL MISSISSIPPI R.M. 634.7

Fig. 1. Approximate sample grid for 10 sample locations at the Prairie du Chien dredge material site.

diversity of the molluscan fauna, to assess changes in the present fauna from past records, to identify species previously unreported at this dredge material site, and to compare the present occurrence of *L. higginsii* with past records.

METHODS AND MATERIALS

The dredge material site at Prairie du Chien, Wisconsin contains about 100,000 cubic meters of dredge material and covers a surface area of about 2 ha. The deposit is up to 3 m deep and consists primarily of sand. Mollusk shells and fragments are readily visible on the surface. A natural succession of vegetation has developed, especially near the periphery.

Ten sample sites were selected on a grid covering the area in which deposits were at least 1 m deep. The sample sites were approximately 25 m apart and centered on the main disposal area (Fig. 1). Sampling began in June and was completed in July 1979.

Each sample site was excavated by shoveling the material into a sieving device (1 X 2 cm mesh of diamond shape) to separate shells from the sand. Many small chips passed through the mesh (especially at site 4), so some shell weight was lost during the process. Few if any identifiable naiad fragments passed through the screen, but many sphaeriids may have been lost during that process. A cubic meter of material was measured by placing a box constructed of plywood, 1 m on a side, on the sample site surface. The retainer box was slid into the excavation as the material was removed to a depth of 1 m. Excavation time was 1 to 3 h per sample site.

Table 1. Weights (kg) of material and percentages of total in parentheses recovered from each sample site.

Site no.	Total weight	Identifiable naiades	Unidentifiable naiades	Gastropods	Rocks	Weight loss ^a
1	34.1	6.3 (18.5)	20.7 (60.7)	1.7 (5.0)	0.9 (2.6)	4.5 (13.2)
2	59.5	19.6 (32.9)	34.3 (57.6)	3.4 (5.7)	1.3 (2.2)	0.9 (1.5)
3	89.1	17.0 (19.1)	65.1 (73.0)	2.6 (2.9)	1.8 (2.0)	2.6 (2.9)
4	258.2	49.8 (19.3)	177.8 (68.9)	3.1 (1.2) ^b	3.9 (1.5)	23.6 (9.1)
5	167.3	40.4 (24.1)	103.4 (61.8)	6.7 (4.0)	2.8 (1.7)	14.0 (8.4)
6	20.5	5.6 (27.4)	11.7 (57.1)	1.4 (6.8)	0.5 (2.4)	1.3 (6.3)
7	50.5	9.5 (18.8)	35.5 (70.2)	1.9 (3.8)	1.0 (2.0)	2.6 (5.1)
8	86.6	21.6 (25.0)	54.9 (63.4)	2.8 (3.2)	1.3 (1.5)	6.0 (6.9)
9	40.9	6.2 (15.1)	25.8 (63.1)	1.8 (4.4)	0.8 (1.9)	6.3 (15.4)
10	<u>6.6</u>	<u>0.7 (10.6)</u>	<u>4.5 (68.2)</u>	<u>0.3 (4.5)</u>	<u>0.1 (1.5)</u>	<u>1.0 (15.2)</u>
Totals	813.3	176.7 (21.7)	533.7 (65.6)	25.7 (3.2)	14.4 (1.8)	62.8 (7.7)

^aDue to sand particles and small shell fragments lost through the sorting process.

^bSome weighed with unidentifiable naiades.

All shells were collected during the sieving operation and any that were obviously or questionably *L. higginsii* were segregated. Some rocks were later found among the collected shells. Samples were packed, transported, and stored in burlap bags. Shells from each sample site were weighed, and following the sorting process, categories of identifiable and unidentifiable naiades, gastropods, and rocks were weighed. Some weight loss was attributed to sand that adhered to the shells originally, but which separated during handling. Later, the sorted material from each site was identified and enumerated.

RESULTS AND DISCUSSION

The total weight of shell material recovered from the 10 sample sites

was 813.3 kg (nearly 1 ton). Weights ranged from 6.6 kg/m³ at site 10 to 258.2 kg/m³ at site 4 (Table 1). Identifiable naiades represented 21.7%, unidentifiable naiades represented 65.6%, gastropods represented 3.2%, and gravel rocks represented 1.8% of the total weight. Unidentifiable shells or fragments were mostly specimens that were deteriorated at the time of dredging, or that were damaged beyond recognition during the dredging, digging, and sorting processes.

Identifiable shells from the 10 sites totaled 6,339 and represented 38 species (Table 2). Site 4 was the richest and yielded 1,737 identifiable valves; site 10 yielded only 51 identifiable valves. *L. higginsii* shells were found at all sites except site 10. The number of *L. higginsii* valves ranged from 1 at site 1 to 9 at site 4. A total of 33 *L. higginsii* valves was recovered.

Table 2. Mollusks of the Mississippi River Dredge Material Site, Prairie du Chien, WI

Naiad mollusks	Numbers identified at sample site										Total	Percent	Rank
	1	2	3	4	5	6	7	8	9	10			
1. <i>Anodonta imbecillis</i> Say, 1829	4	3	---	1	2	2	2	4	6	3	27	0.43	19
2. <i>Anodonta grandis corpulenta</i> Cooper, 1834	---	1	---	1	1	---	---	---	---	---	3	0.05	30
3. <i>Strophitus undulatus undulatus</i> (Say, 1817)	6	2	1	6	6	1	2	2	1	---	27	0.43	19
4. <i>Alasmodonta marginata</i> Say, 1818	---	---	---	---	---	---	---	---	1	---	1	0.02	32
5. <i>Arcidens confragosus</i> (Say, 1829)	3	---	1	1	2	---	1	---	1	---	9	0.14	25
6. <i>Lasmigona complanata</i> (Barnes, 1823)	---	---	---	1	2	---	---	2	---	---	5	0.08	28
7. <i>Lasmigona costata</i> (Rafinesque, 1820)	---	---	---	3	---	---	---	---	---	---	3	0.05	30
8. <i>Megalania nervosa</i> (Rafinesque, 1820)	1	3	---	4	8	---	---	4	1	---	21	0.33	21
9. <i>Tritogonia verrucosa</i> (Rafinesque, 1820)	2	---	1	4	5	3	3	5	1	---	24	0.38	20
10. <i>Quadrula quadrula</i> (Rafinesque, 1820)	1	6	1	13	16	4	2	6	3	---	52	0.82	15
11. <i>Quadrula fragosa</i> (Conrad, 1835)	---	1	---	---	---	---	---	---	1	---	2	0.03	31
12. <i>Quadrula metanevra</i> (Rafinesque, 1820)	6	2	11	21	12	1	3	9	3	---	68	1.07	13
13. <i>Quadrula nuditata</i> (Rafinesque, 1820)	11	57	21	64	85	15	16	39	21	5	334	5.27	6
14. <i>Quadrula pustulosa pustulosa</i> (Lea, 1831)	23	53	53	222	126	23	53	99	24	4	680	10.73	3
15. <i>Amblema plicata plicata</i> (Say, 1817)	82	207	152	357	287	63	83	182	32	12	1,457	22.98	1
16. <i>Fusconaia ebena</i> (Lea, 1831)	31	97	157	525	308	24	63	161	54	4	1,424	22.46	2
17. <i>Fusconaia flava</i> (Rafinesque, 1820)	18	26	50	122	73	18	40	52	29	3	431	6.80	4
18. <i>Plethobasus cyphus</i> (Rafinesque, 1820)	1	1	---	2	---	---	---	1	---	---	5	0.08	28
19. <i>Pleurobema sintoxi</i> (Rafinesque, 1820)	3	5	15	43	18	2	11	3	4	1	105	1.66	11
20. <i>Elliptio crassidens crassidens</i> (Lamarck, 1819)	3	3	3	18	9	---	1	5	1	1	44	0.69	16
21. <i>Elliptio dilatata</i> (Rafinesque, 1820)	---	---	3	2	5	---	3	---	---	---	13	0.21	24
22. <i>Obliquaria reflexa</i> (Rafinesque, 1820)	7	19	17	66	50	3	29	33	19	3	251	3.96	8
23. <i>Actinonaias ligamentina carinata</i> (Barnes, 1823)	5	9	36	44	36	1	3	8	6	1	149	2.35	10
24. <i>Plagiola lineolata</i> (Rafinesque, 1820)	1	---	2	4	---	---	---	---	---	---	7	0.11	26
25. <i>Obovaria olivaria</i> (Rafinesque, 1820)	10	27	37	77	64	10	19	19	26	2	291	4.59	7
26. <i>Truncilla truncata</i> Rafinesque, 1820	11	24	14	45	64	8	8	16	19	1	210	3.31	9
27. <i>Truncilla donaciformis</i> (Lea, 1827)	32	90	26	46	99	29	20	45	38	5	430	6.78	5
28. <i>Leptodea fragilis</i> (Rafinesque, 1820)	1	10	1	8	2	5	4	7	4	1	43	0.68	17
29. <i>Potamilus alatus</i> (Say, 1817)	2	3	---	1	2	2	4	---	3	---	17	0.27	22
30. <i>Potamilus laevis</i> (Lea, 1829)	---	---	---	1	2	2	---	---	---	1	6	0.09	27
31. <i>Toxolasma parvus</i> (Barnes, 1823)	---	1	---	---	2	---	---	---	---	---	3	0.05	30
32. <i>Ligumia recta</i> (Lamarck, 1819)	3	3	3	12	10	5	3	12	1	2	54	0.85	14
33. <i>Lampsilis teres forma teres</i> (Rafinesque, 1820)	1	2	2	2	3	2	---	1	3	---	16	0.25	23
34. <i>Lampsilis teres forma quadricostata</i> (Lea, 1831)	---	---	---	---	1	---	---	---	---	---	1	0.02	32
35. <i>Lampsilis radiata luteola</i> (Lamarck, 1819)	---	1	---	1	2	---	---	---	---	---	4	0.06	29
36. <i>Lampsilis higginsii</i> (Lea, 1857)	1	4	5	9	6	1	3	3	1	---	33	0.52	18
37. <i>Lampsilis ventricosa</i> (Barnes, 1823)	11	10	8	10	15	5	5	14	8	2	88	1.39	12
38. <i>Epioblasma triquetra</i> (Rafinesque, 1820)	---	---	---	1	---	---	---	---	---	---	1	0.02	32
Total specimens per site	280	670	620	1,737	1,323	234	381	732	311	51	6,339	100.01	
Number of species per site	27	28	24	34	32	23	24	25	27	17	38		
Other mollusks													
Gastropod sp.	683	1441	1554	1166 ^a	2560	555	715	971	806	143	10594		
Sphaeriidae sp.	1	4	1	4	7	160	3	5	---	---	185		

^aIncomplete count for site 4.

Among the 38 species, *L. higgins* ranked 18th and represented 0.52% of the total number of specimens. Their density averaged about three valves per cubic meter of dredge material sampled.

Some valves of *L. higgins* that had been buried under 0.75 m of sand for 3 years were nearly as well preserved as fresh dead specimens recovered in 1976 shortly after the dredging. Evidence of decayed organic material inside some valves, appearance of the nacre, and general condition of the valves suggested that about one-half of the *L. higgins* could have been alive at the time of dredging. Six valves of *L. higgins* were recovered from the surface within 3 m of the excavation at site 3. These valves and eight additional *L. higgins* found elsewhere on the surface were not included in the quantitative sampling totals.

Ambelma plicata plicata has been cited in recent surveys as one of the most abundant species in the Upper Mississippi River (Fuller, 1978; Mathiak, 1979; Havlik, 1980b; Thiel et al., 1980). This species ranked number one in abundance (1,457 specimens) in our study, and its populations appear dominant in this particular area. *Fusconaia ebena* was formerly the most common naiad in the Mississippi River (Coker, 1919), and they ranked second in abundance (1,424 specimens) in our study. However, the closing of the Keokuk power dam in 1913 prevents the host fish, skipjack herring (*Alosa chrysichloris*), from migrating upstream (Coker, 1929), and the species no longer reproduces in the Prairie du Chien area. Our finding of mostly deteriorated shells of *F. ebena* and *Elliptio crassidens crassidens* verifies a lack of recent reproduction due to the absence of the host fish. In contrast to the more abundant species, single specimens of *Alasmodonta marginata*, *L. teres forma anodontoides*, and *E. triquetra* were found.

New site records for five naiad species were recorded from the Prairie du Chien dredge material site. The species and numbers are *A. marginata* (1), *Lasmigona costata* (3), *Quadrula fragosa* (2), *L. radiata luteola* (4), and *E. triquetra* (1). The latter was recorded from the Prairie du Chien area for the first time.

Several species were represented mostly by deteriorated shells: *A. marginata*, *L. costata*, *Tritogonia verrucosa*, *F. ebena*, *Pleurobema sintoxia*, *E. c. crassidens*, *Actinonaias ligamentina carinata*, and *E. triquetra*. In contrast, very few deteriorated shells of *A. p. plicata* were found, and most were probably alive at the time of the 1976 dredging.

Gastropod and sphaenid shells from the 10 sites numbered 10,594 and 185, respectively (Table 2). These shells were thin and lightweight compared to naiad shells as reflected by weights and numbers in Tables 1 and 2. The bulk of the gastropods found during this study appeared to be *Campeloma* sp. and *Viviparus* sp., and only 124 were *Oxytrema* sp. Sphaenid shells were so fragile and small (mostly under 3 mm) that many were lost through the sorting sieve. Those collected were found in sand adhering to other shells.

Site 4 was apparently a discharge point because some strata consisted almost entirely of shells or shell fragments. Digging was extremely difficult through such strata because the shovel would not penetrate the shell material. The greatest weight and number of identifiable shells were reported from this site, but many fragments were lost through the sieve.

During the digging process we observed shell layers that had apparently settled out during the deposition of dredge material. These layers probably represented the surface of the river bottom area being dredged, and those shell densities are reflected in the deposited material. The substrate inhabited by the live naiades obviously contained numerous deteriorated shells and some small rocks. The shells and fragments apparently have helped to support and maintain the stability of the channel substrate. In consideration of the abundance of live and dead naiades at the time of dredging, the shell and rock substrate must provide excellent habitat for growth, survival, and reproduction of mollusks.

CONCLUSIONS

1. Molluscan fauna found at the Prairie du Chien dredge material site was diverse (38 species) and abundant (up to 1,737 valves per cubic meter).
2. The endangered *L. higgins* ranked 18th in occurrence, accounted for only 0.52% of the identifiable shells, and averaged three valves per cubic meter of dredge material. A total of 33 valves was recovered.
3. In comparison to previous records, molluscan fauna has changed in the Prairie du Chien area; decreases evident for live *F. ebena* and *E. c. crassidens* can be attributed to lack of the host fish. Reasons for the decline of several other species are not clear. *A. p. plicata* appears to be on the increase based on the presence of large numbers of adults and juveniles.
4. Five naiad species were collected at this study site for the first time, and one of these, *E. triquetra*, had never been reported in the Prairie du Chien area.
5. The East Channel at Prairie du Chien obviously contains very suitable habitat for *L. higgins*.
6. This site is an ideal location for studying long-term aging of exposed or buried shells.

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POLYPLACOPHORA OF DRY TORTUGAS, FLORIDA WITH COMMENTS ON *ISCHNOCHITON HARTMEYERI*

THIELE 1910

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INTRODUCTION

The Dry Tortugas, located in the extreme southeastern Gulf of Mexico, contain seven small islands (total area 46 hectares) surrounded by nearly 23,000 hectares of shallow (<10 m) carbonate sands, seagrass

beds, and coral reefs. Ft. Jefferson National Monument was established in 1935 to protect the historic and natural resources of Dry Tortugas; the monument is administered by the National Park Service (NPS). Physiography and major faunal components of the area are described by Davis (in press).

In 1978, I visited Dry Tortugas to assist NPS biologists studying feeding habits of the spiny lobster, *Panulirus argus*. Examination of lobster stomach contents during the subsequent year revealed a high incidence of polyplacophoran ("chiton") remains, principally radulae but also including valves of several species. I returned to Dry Tortugas in

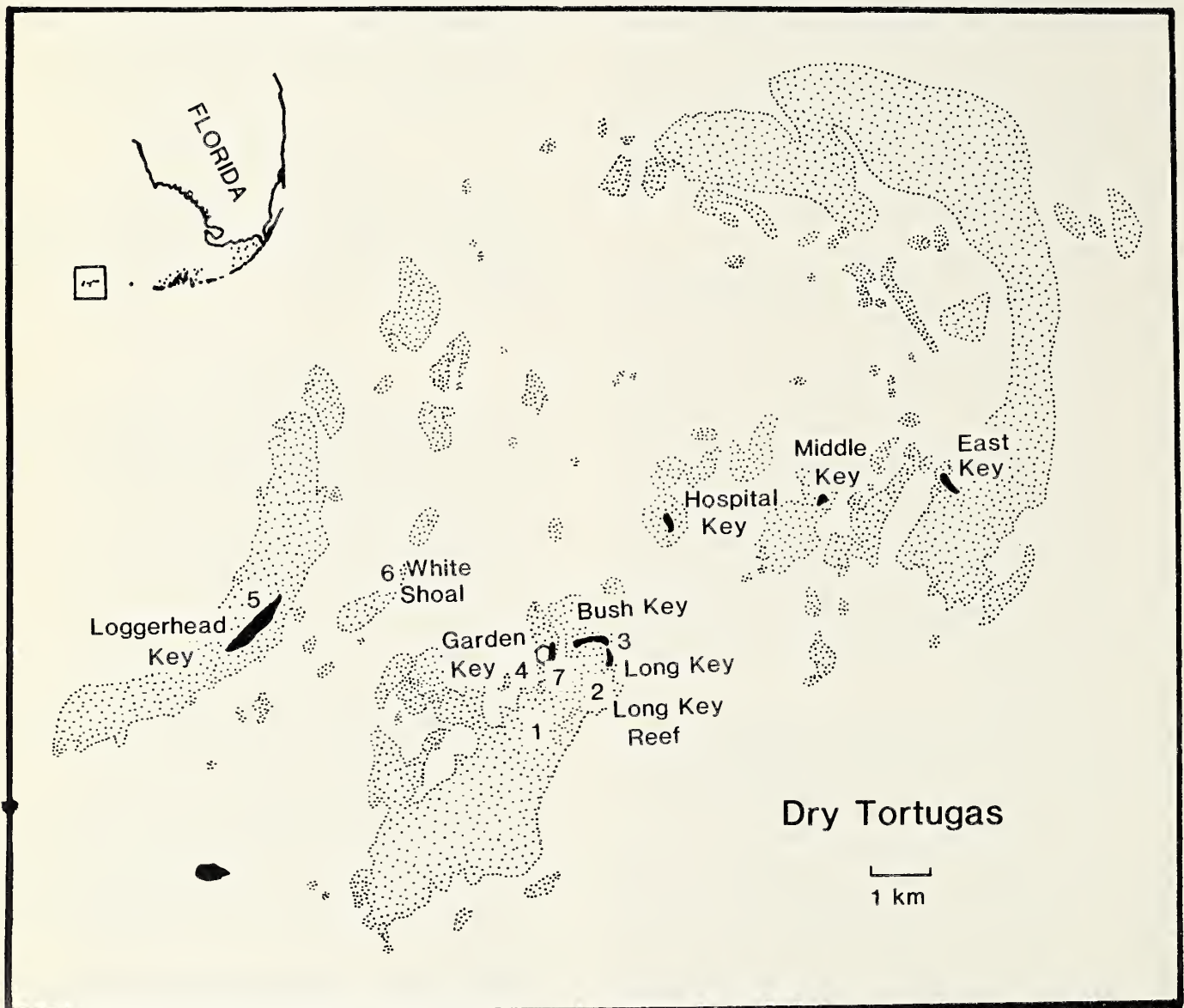


Figure 1. Station locations, Dry Tortugas polyplacophoran study.

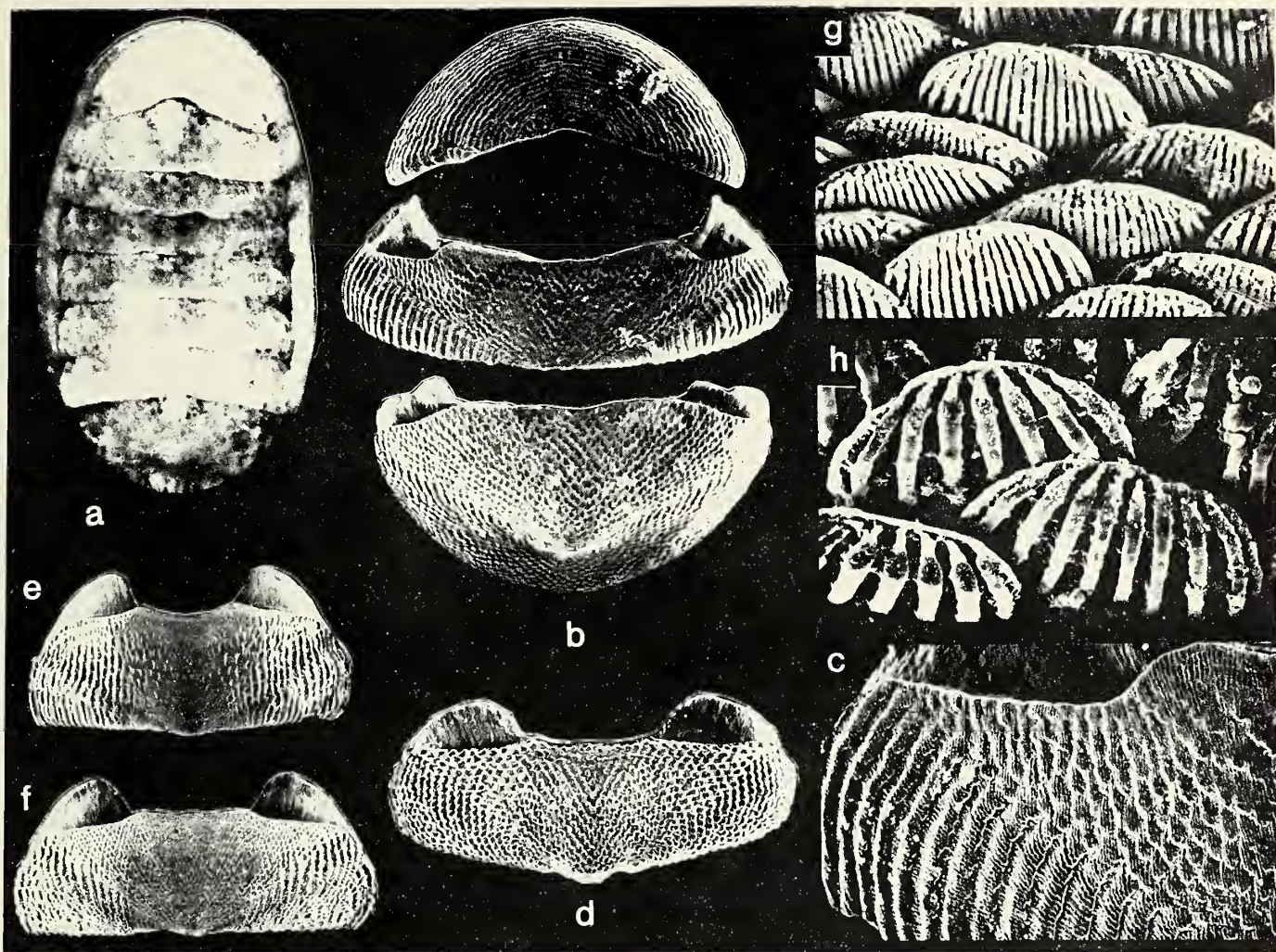


Figure 2a, *Ischnochiton hartmeyeri*, entire specimen, length 6.1 mm (x12); 2b, same, specimen length 6.0 mm, valves I (top), IV and VIII (x22); 2c, same specimen, valve IV, left lateral margin (x75); 2d, *Ischnochiton papillosus*, specimen length 5.8 mm, valve IV (x22); 2e, *Ischnochiton erythronotus*, specimen length 11.9 mm,

valve IV (x11); 2f, *Ischnochiton striolatus*, specimen length 11.8 mm, valve IV (x11); 2g, *I. hartmeyeri*, same specimen as b, girdle scales (x750); 2h, *I. papillosus*, same specimen as d, girdle scales (x750). All specimens from Dry Tortugas.

May 1979 to collect potential lobster prey. A diverse chiton assemblage was revealed, but little time was available to canvas the fauna. I returned again in October 1979 and devoted three full days and parts of two others sampling chitons.

METHODS AND MATERIALS

Seven stations were sampled (Figure 1; Table 1), some during both visits. Most stations were located near Garden Key (Ft. Jefferson) because of accessibility via small boat, but use of the NPS vessel *Activa* allowed visits to the submerged bank at White Shoal and to the only massive beach rock at Dry Tortugas, located on the west side of Loggerhead Key.

Chitons were collected from the intertidal zone to depths of approximately 4 m, but most were from depths of 2 m or less. Specimens usually occurred on undersides of coral rubble or dead gastropod shells (principally *Strombus gigas*); loose bricks near the moat wall at Ft. Jefferson also yielded many specimens.

Living specimens were relaxed and extended on glass slides in

seawater, bound to the slides, and then fixed in a solution of equal parts ethyl alcohol, glycerine and water.

RESULTS

A total of 450 specimens comprising 14 species were collected (Table 2). Coral rubble at the patch reef (Station 1) yielded 24 specimens of 9 species. Only *Acanthochitona* sp. and *Stenoplax purpurascens* were relatively common.

Thirteen species totaling 174 specimens were found at Long Key Reef (Station 2), where the extensive rubble zone provided excellent collecting opportunities. Few chitons occurred above the low tide line, nearly all being found under rocks or shells in depths ranging from several cm to 1 m where temperatures were markedly cooler. Principal species at Long Key Reef were *Ischnochiton erythronotus*, *Calloplax janeirensis*, *I. striolatus*, *Stenoplax floridanus* and *S. purpurascens*.

Station 3, located in an area of heavy wave surge, contained massive submerged rocks and coral heads but few rocks small enough to overturn. Even considering scarcity of rocks suitable for sampling, the

TABLE 1. STATION DATA, DRY TORTUGAS POLYPLACOPHORAN COLLECTING SITES

Station	Location	Depth (m)	Date
1	Patch reef near former site of Bird Key	2.0	5/11,12/79
2	Long Key Reef	0-1.0	5/11,12/79 10/3,4/79
3	Southeast end Bush Key	1.0-3.0	5/13/79
4	Near moat wall, west side Garden Key	1-2.0	5/13,14/79 10/5/79
5	West side Loggerhead Key	0-1.0	10/2/79
6	White Shoal	3.0-4.0	10/3/79
7	Southwest corner Garden Key	1.5-2.0	10/6/79

fauna appeared reduced as compared to the diverse assemblage at nearby Long Key Reef. *Ischnochiton erythronotus*, the most common species at Long Key Reef and Garden Key, was absent at Station 3.

In the area near the moat wall at Ft. Jefferson (Station 4) 213 specimens of 10 species were found. The same species common at Long Key Reef were common here, but *Acanthochitona hemphilli* and *Ischnochiton papillosus* were also common. Most of the chitons were found on loose bricks. However, situation of bricks in the environment determined the species associated with them. Virtually all *Ischnochiton* and *Stenoplax* species occurred on undersides of bricks slightly buried in surrounding sediments, whereas species of *Lepidochitona*, *Acanthochitona*, *Cryptoconchus* and *Calloplax* occurred among encrusting sponges, bryozoans and algae within piles of bricks. *Acanthochitona hemphilli* was notably common in the latter habitat; more specimens were observed than were collected. No polyplacophorans were found on vertical moat walls.

One hour sampling of the rock beach at Loggerhead Key (Station 5), produced no chitons but four species totaling nine specimens were collected in the nearby rubble zone; all species also occurred at other stations.

Substrate at White Shoal (Station 6) consisted of rubble, principally remnants of staghorn coral (*Acropora cervicornis*). Only one specimen was found during 1 hr of sampling.

Station 7, characterized by scattered bricks and rocks on sand, was surveyed for approximately 45 minutes; it supported an assemblage of four *Ischnochiton* and two *Stenoplax* species, including relatively common *I. hartmeyer*, a species rare or absent elsewhere.

DISCUSSION

The Dry Tortugas have yielded several important polyplacophoran collections (Kaas, 1972), but the list of species known to occur there has increased slowly. Dall (1889a) mentioned *Ischnochiton* (*Stenoplax*) *limaciformis* Sowerby [probably = *Stenoplax purpurascens* fide Kaas (1972)] and *Notoplax* [= *Cryptoconchus*] *floridanus*. In his catalogue of mollusks from the southeastern United States, Dall (1889b) listed *Acanthochiton astriger* Reeve [= *Acanthochitona spiculosa*] from Dry Tortugas. Pilsbry (1893) reiterated two of Dall's records [as *Acanthochites astriger* and *Acanthochites* (*Cryptoconchus*) *floridanus*] but added no new species to the list. Thiele (1910) reported *Cryptoconchus floridanus*, *Calloplax janeirensis*, *Ischnochiton* [= *Stenoplax*] *floridanus* and *I. erythronotus*, and described *Ischnochiton hartmeyer* from a single specimen collected at Tortugas. Kaas (1972) listed nine species from Dry Tortugas, including the seven previous plus *Acanthochitona hemphilli* and *A. pygmaea*. Kaas only examined Tortugas specimens of *Acanthochitona hemphilli*, *Calloplax janeirensis* and *Ischnochiton erythronotus*, repeating previous records for the other six species; he credited to Thiele the record for *A. pygmaea*, but I failed to find that record in Thiele (1910).

Table 2. NUMBERS OF POLYPLACOPHORANS COLLECTED AT DRY TORTUGAS STATIONS.¹

Species	Station							Total
	1	2	3	4	5	6	7	
Lepidochitonidae								
<i>Lepidochitona lionsonis</i> (Dall and Simpson, 1901)	1	0/2		0/2				5
Cryptoplacidae								
<i>Acanthochitona hemphilli</i> (Pilsbry, 1893)	1	3/2		8/6				20
<i>Acanthochitona pygmaea</i> (Pilsbry, 1893)		0/4		0/1				5
<i>Acanthochitona</i> sp.	6	1/0						7
<i>Cryptoconchus floridanus</i> (Dall, 1889)	2	3/1		4/1				11
Ischnochitonidae								
<i>Callistochiton shuttleworthianus</i> Pilsbry, 1893		0/2			1			3
<i>Calloplax janeirensis</i> (Gray, 1828)	1	5/13		5/9	1			34
<i>Ischnochiton erythronotus</i> (C.B. Adams, 1845)	1	4/99		0/103	1		10	218
<i>Ischnochiton hartmeyer</i> Thiele, 1910		0/1	1				7	9
<i>Ischnochiton papillosus</i> (C.B. Adams, 1845)				1/11			3	15
<i>Ischnochiton rugulatus</i> (Sowerby, 1832)		1/0						1
<i>Ischnochiton striolatus</i> (Gray, 1828)	2	0/12	1	1/22		1	3	42
<i>Stenoplax floridana</i> (Pilsbry, 1892)	2	2/10		0/6			1	21
<i>Stenoplax purpurascens</i> (C.B. Adams, 1845)	8	0/9	2	7/26	6		1	59
Total	24	19/155	4	26/187	9	1	25	450

¹ 0/0 = May/October numbers at stations sampled during both months.

Present collections add *Lepidochitona lionsonis*, *Callistochiton shuttleworthianus*, *Ischnochiton papillosus*, *I. rugulatus* and *I. striolatus*, and confirm the presence of *Acanthochitona pygmaea*. The species designated *Acanthochitona* sp. is underscribed and is not conspecific with Florida specimens presently called *A. spiculosa* but may be the species previously reported from Dry Tortugas under that name. The list of polyplacophorans known from Dry Tortugas is therefore increased to 14, possibly 15, species.

The classification of Florida and Caribbean Polyplacophora is presently unsettled. For convenience, I follow for the most part that of Kaas (1972), recognizing that his arrangement differs considerably from those of Smith (1960), Keen (1971) and Abbott (1974). I am aware of Ferreira's (1978) paper wherein he synonymized several species in *Stenoplax* and *Ischnochiton*; I retain these separately because I believe both problems require further study. Specimens of *S. purpurascens* were the only *Stenoplax* found at Stations 3 and 5 and were usually more common than *S. floridana* at other stations. However, Ferreira correctly noted that some specimens are difficult to assign to either species, and identities of some present specimens remain estimates. Small juveniles of *Ischnochiton erythronotus* and *I. striolatus* were difficult to distinguish, but larger specimens differed distinctly. *Ischnochiton erythronotus* was far more common than *I. striolatus* at shallow stations, but *I. striolatus* also occurred at deeper stations where *I. erythronotus* was absent. Specimens of *I. papillosus* did not overlap morphologically with *I. erythronotus* nor with *I. striolatus*. *Ischnochiton papillosus* occurred only at Garden Key stations.

Ecological separation is also suggested among the species of *Acanthochitona*; *A. hemphilli* occurred rarely at reef and patch reef stations but was common on encrusted bricks at Garden Key. Nearly all *A. pygmaea* occurred at the reef, and most *Acanthochitona* sp. occurred at the patch reef.

I agree with Keen (1971) that *Ischnochiton rugulatus* (Sowerby, 1832) seems indistinguishable from *I. boogii* Haddon, 1866; the former name has precedence. Only one 5 mm juvenile was collected.

Thiele's description (translated to English by Kaas (1972)) of his single 5.5. mm specimen of *Ischnochiton hartmeyer* from Bird Key Reef

is reasonably accurate. Present specimens range in length from 4.8 to 6.7 mm. Small brown spots "in the median parts" mentioned in the original description appear as fine brown lines on all specimens I examined (Figure 2a). Fine but distinct concentric furrows crossed by numerous microscopic radial striae on the anterior valve and posterolateral areas of intermediate valves (Figure 2b, c) distinguish the species from *I. papillosus* and small *I. erythronotus* and *I. striolatus* (Figure 2d-f), all of which it resembles superficially until viewed under magnification. Thiele described about 16 narrow riblets on very small scales from the upper part of the girdle; riblet numbers on present material range from 16-18 (Figure 2g). This character also distinguishes *I. hartmeyer* from the previous three species, all of which possess about 7-9 riblets on considerably larger scales (Figure 2h). Sutural laminae of *I. hartmeyer* are short and sharply attenuated anteriorly (Figure 2b), resembling those of juveniles of some other *Ischnochiton* species. However, the 6.0 mm specimen dissected for illustration carried about 50 large eggs indicating maturity.

Comparisons of small (seldom > 4 mm length) chitons from coastal rubble zones near Tampa Bay, Sarasota Bay, Sanibel Island (all Florida Gulf coast) and Hutchinson Island (Florida central east coast) indicate these to be conspecific with *I. hartmeyer*, so known range of the species is extended northward along both Florida coasts. I have also examined a single valve of this species from the Florida Middle Ground. Rios (1975) listed *I. hartmeyer* from off Alagoas, Brazil, in 36 m depth but did not illustrate specimens. Considering the range otherwise known, that record should be verified.

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MOTOR PERFORMANCE AND JET PROPULSION IN NAUTILUS: IMPLICATIONS FOR CEPHALOPOD PALEOBIOLOGY AND EVOLUTION

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ABSTRACT

Cinematography of locomotory behavior in adult *Nautilus pompilius* suggests that periodic inward-outward body movements produced by action of the paired cephalic retractor muscles generate some of the animal's propulsive force. Equilibrium control is achieved through the inherent static stability of the shell. When a comparison of thrust/total mass; propulsive muscle mass/total mass; and propellant volume and velocity, is made among selected fish and cephalopods, *Nautilus* seems to be much more weakly powered and inefficient than the others. Estimates of swimming speed in fossil ectocochliate cephalopods, based on the same parameters, suggest most were slower than *Nautilus*. The relative ineffectiveness of the ectocochliate propulsion mechanism is due mainly to retention of the shell as a major feature of adaptive design. The evolutionary history of the major groups of swimmers (i.e. ectocochliates, endocochliates, fish) seems to be governed by advances in the sophistication of buoyancy and propulsion mechanisms. Ectocochliates have declined partly because their unique buoyancy system based on a heavy shell has precluded the opportunity to develop an efficient means of

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propulsion, comparable to the propulsion mechanisms of fish and endocochliates.

INTRODUCTION

Nautilus has become an object of keen interest to cephalopod paleontologists because it is the best living link to the myriads of fossil ectocochliate cephalopods that populated Paleozoic and Mesozoic seas. Studies on modern *Nautilus* (Denton & Gilpin-Brown 1966; Ward et al. 1977; Chamberlain 1978; Ward & Martin 1978; Saunders & Spinoza 1978, 1979; Ward 1979; Collins et al. 1980; Kanie et al. 1980) have been particularly rewarding in interpreting buoyancy control and life habits of fossil forms. In this paper I briefly examine some aspects of the propulsion of *Nautilus*, and the significance of propulsion in cephalopod paleobiology and evolution.

EQUILIBRIUM CONTROL

Equilibrium control is an essential part of any form of locomotion. Nektonic animals deal with this requirement by using a control system combining the inherent static stability of their bodies with compensatory movements of body and appendages. Most fish, for example, have low stability and rely on movements of their flexible body and fins for equilibrium control. This is a highly effective system, and underlies the high degree of agility and maneuverability characteristic of most fish. Shelled

cephalopods like *Nautilus* can not use this approach because the large, rigid shell precludes the necessary body flexibility and because the animal's tentacles are poorly positioned to maintain swimming trim. Instead, these animals rely on the relatively high stability of their shells as the major means of equilibrium control (Trueman 1941; Raup & Chamberlain 1967; Raup 1967; Chamberlain, 1980). This system is not nearly as sophisticated as that of fish because it lacks a means for precision control, and it is this situation that produces the poor maneuverability typical of the locomotion of *Nautilus* (Chamberlain 1976, 1980).

SWIMMING MOVEMENTS

Although virtually all cephalopods develop propulsive force in basically the same manner - by expelling a jet of water under high pressure - the anatomy of the propulsive mechanism differs somewhat from group to group. In this respect, *Nautilus* is unusual in having a flap-like hyponome rather than a tubular one, and a weakly muscled mantle (Bidder 1962). Another important feature distinguishing *Nautilus* in this regard is the forward-backward rocking of the shell that accompanies the progression of the animal through the water.

Figure 1 shows the general nature of these rocking motions. The sketches included here are based on tracings taken from a frame-by-frame film analysis of a freely swimming animal. During the active phase of propulsion, when water is expelled from the hyponome, the shell rocks forward. This is followed by a backward rotation of the shell during the recovery phase when water is drawn into the mantle cavity.

Shell rotation is readily attributable to the interaction of the rotational moments due to static stability and propulsive force, and serves to illustrate the importance of static stability in equilibrium control. The application of thrust (propulsive force) near the ventral margin of the peristome during the active phase of the propulsive cycle sets up a moment which rotates the shell forward (Figure 2A) until it is balanced by

the restoring moment due to static stability acting in the opposite direction. When the propulsive force is removed during the recovery phase of propulsion, this propulsive moment disappears, and the shell rotates back toward its initial position under the influence of the stability moment (Figure 2B). The next application of propulsive force again carries the shell forward. The angle through which the shell rotates varies from pulse to pulse, but normally does not exceed $\pm 10^\circ$ from the stable rest position (Figure 3A). Rotation is observed when the animal is swimming backward as well as forward, although rotational angles tend to be higher for the former because swimming velocity, and hence thrust, generally are greater in this orientation.

Cinematographic analysis also shows that inward-outward movements of the body occur during locomotion. Figure 3B indicates that the body moves inward relative to the peristome during active propulsion, and then outward during the recovery phase. The evident correlation in timing between shell rotation, application of thrust, and movement of the body, suggests that extension and retraction of the body forms an integral part of the propulsive system. Outward extension of the body would allow the mantle cavity to expand and fill quickly with water. Inward contraction would compress the mantle cavity, thus elevating its hydrostatic pressure, and perhaps producing a large part of the thrust developed by the animal.

Body retraction is produced by flexing of the large, paired cephalic retractor muscles that lie over the mantle cavity. Thus, it would seem that these muscles are an important component of the propulsive system of *Nautilus*, as postulated by Mutvei & Reymont (1973). Their activity during propulsion is analagous to the movements of the cephalic retractors in some endocochliates (A.M. Bidder, G. Voss - pers. comm. 1980), particularly ommastrephid squids (R. Toll - pers. comm. 1980).

Although it is probable that *Nautilus* makes poor paradigm for inferring anatomic details of most fossil ectocochliates, especially ammonoids, there can be little doubt that mass distribution in all ectocochliates is

TABLE 1

		Thrust Coeff.	Froude Eff.	Mass Ratio	Exhaust Ratio
Ectocochliates	<i>Nautilus pompilius</i>	0.04	0.25	0.10	0.17
	<i>Octopus vulgaris</i>	0.4		0.10	0.14
	<i>Eledone moschata</i>			0.20	0.50
Endocochliates	<i>Loligo vulgaris</i>	1.3	0.22	0.35	0.57
	<i>Sepia officinalis</i>	0.7	0.37	0.30	0.60
Fish	<i>Salmo gairdneri</i> (rainbow trout)		0.61-0.81	0.60	6.40
	<i>Leuciscus leuciscus</i> (dace)			0.55	
	<i>Carassius auratus</i> (goldfish)			0.40	
	<i>Perca flavescens</i> (perch)			0.33	

Table 1. Propulsive parameters of *Nautilus* and other swimmers. Thrust coefficient = thrust/total weight. Froude efficiency = useful power/(useful power + power lost to fluid). Mass ratio = mass of propulsive muscles/total mass. For *Nautilus* mass ratio values are based on hyponomic and cephalic retractor muscles; for endocochliates, on mantle muscles; for fish, on trunk muscles. Exhaust ratio = mass of propellant/total mass. For *Nautilus*

exhaust ratio values are based on volume of water in a single large squirt; for endocochliates, on mantle cavity volume; for fish, on volume of water accelerated by caudal fin in 1 second. Data for endocochliates from Trueman & Packard (1968). Data for fish from Bainbridge (1960); Webb (1975); Alexander (1977).

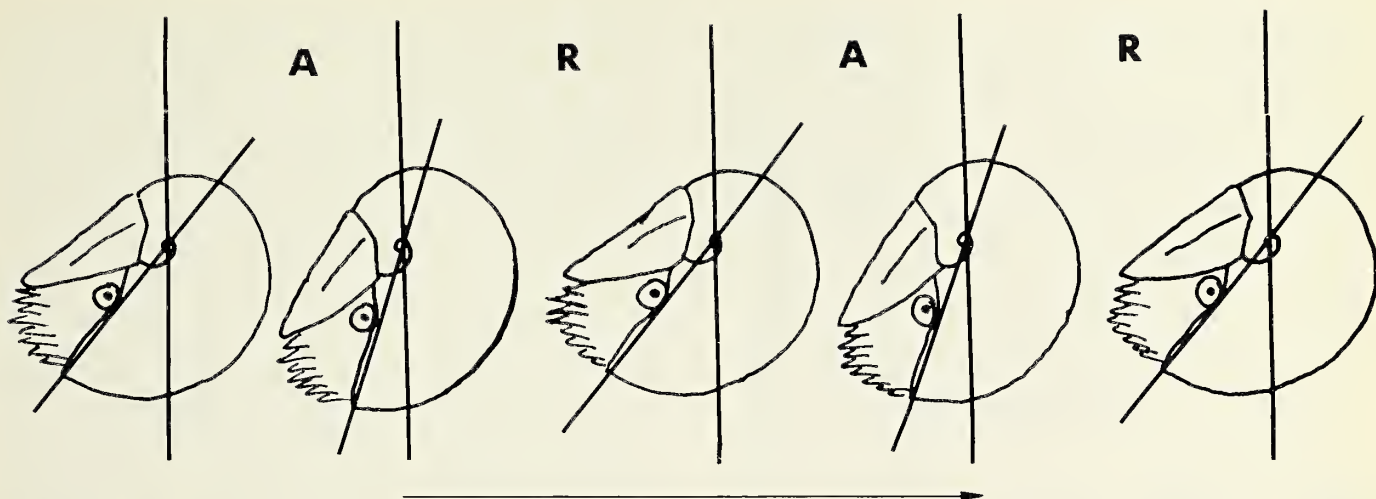


Figure 1. Rocking movements of swimming *Nautilus*. Horizontal arrow shows direction of motion of animal. A: active phase of propul-

sive cycle; water expelled from hyponome. R: recovery phase of propulsive cycle; water drawn into mantle cavity.

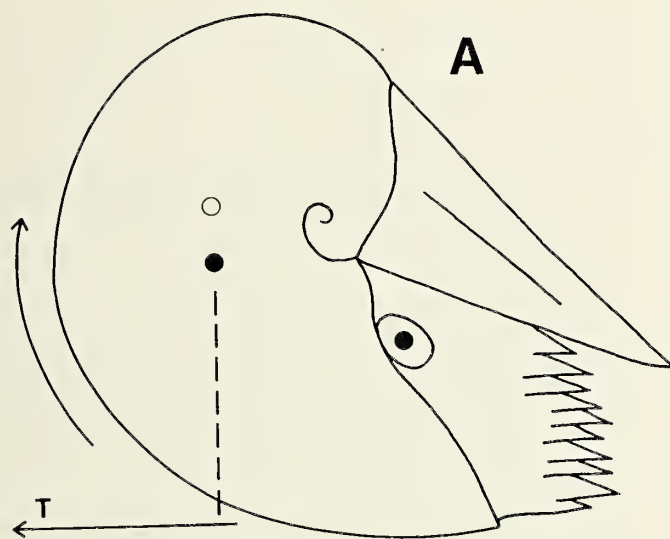
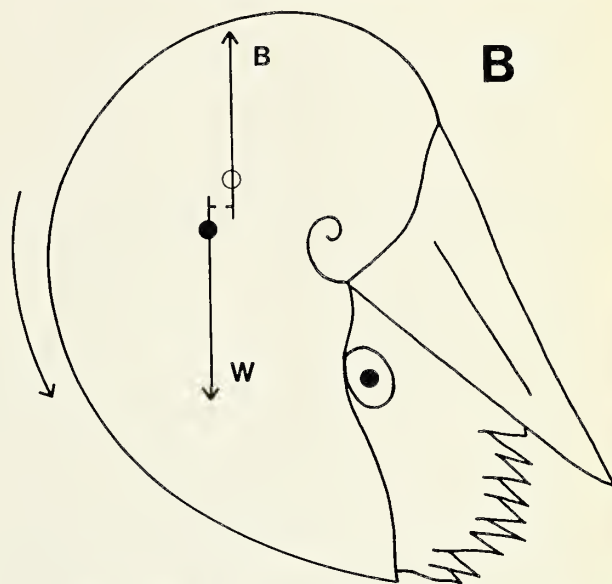


Figure 2. Rotational moments acting on swimming *Nautilus*. Dot - center of mass. Circle - center of buoyancy. Curved arrow shows direction of shell rotation. A: inception of active propulsion. T -



thrust. Dashed line - moment arm of thrust. B: inception of recovery phase. W - weight. B - buoyant force. Dashed line - moment arm of weight-buoyancy couple.

essentially the same (all have a camerated shell with a tissue filled body chamber). Thus, it seems certain that, like *Nautilus*, fossil forms relied on static stability for equilibrium control, and would have exhibited the same ungainly rotational movements. Retractor muscle scars are known from many fossils (e.g. Kennedy & Cobban 1976). Although the functioning of these muscles is not yet clear in the fossils, the generally larger size of such scars in nautiloids as compared to ammonoids may suggest a higher level of locomotory activity for the ancestors of *Nautilus* than for contemporary ammonoids. Certainly, analysis of muscle scars is a fruitful area for further work.

SWIMMING VELOCITY

The swimming velocity of *Nautilus* has received little attention de-

spite its obvious importance in evaluating locomotory performance. Cinematographic analysis (Chamberlain & Westermann 1976) indicates a speed in the order of 25 cm/sec. Ward et. al. (1977) obtained similar speeds in tests on freshly captured animals. These values are thought to represent maximum velocities because the specimens tested were undoubtedly considerably stressed by the presence of divers. However, present tests with captive animals (Chamberlain unpubl. data) indicate a capacity for slightly higher velocities over short distances, as well as a range of swimming modes similar to the slow swimming, sustained cruising, and high speed bursts seen in many fish and squids.

Swimming velocities of fossil ectocochliates are difficult to deal with because body parts and behavior necessary for evaluating this parameter are not preserved in the fossils. Yet, by making some simplifying assumptions about instantaneous thrust, it is possible to calculate swimming

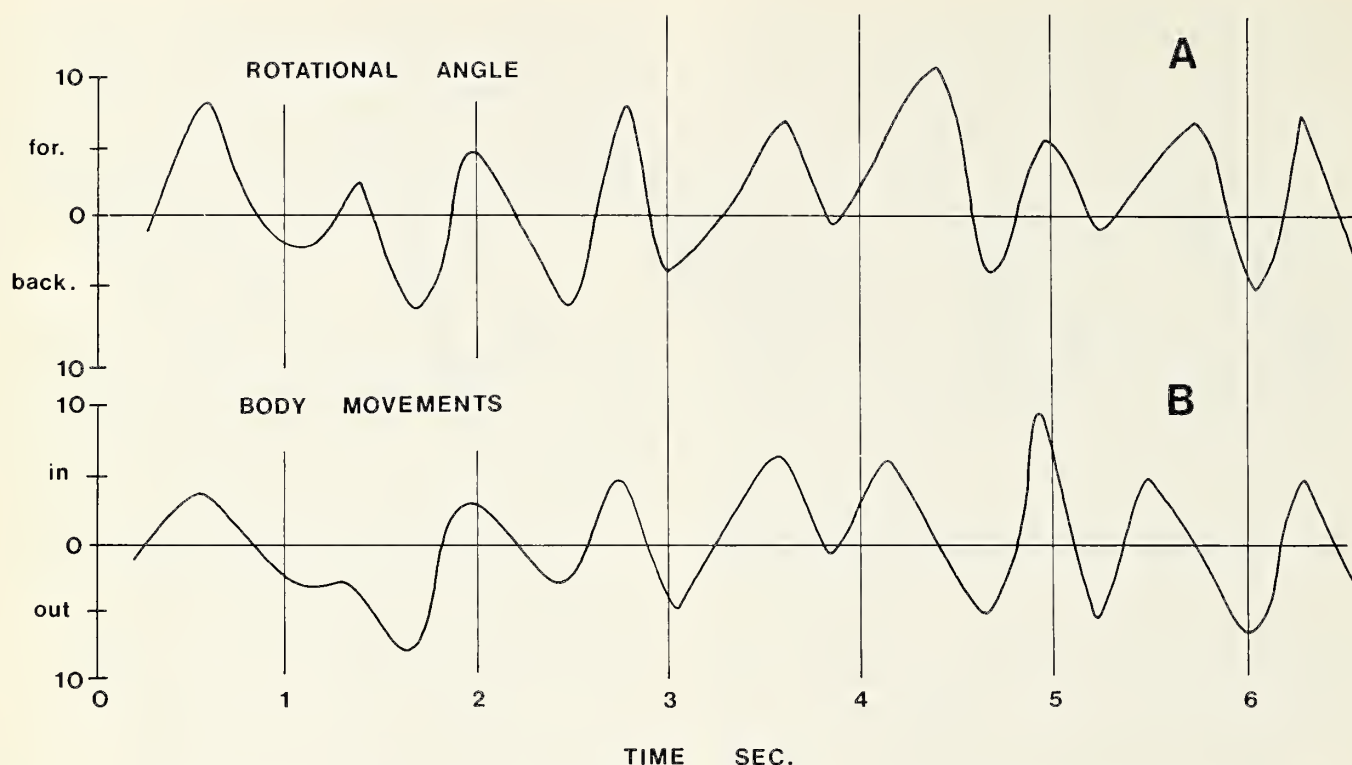


Figure 3. Cinematographic record of swimming movements of *Nautilus*. A: rotational angle of shell. For. - forward rotation. Back. - backward rotation. Angles on ordinate in degrees. B: move-

ments of body relative to peristome. in - inward retraction of body. out - outward extension of body. Units on ordinate are mm.

velocity for a fossil cephalopod in terms of its rotation angle, stability, total mass, and drag coefficient (Chamberlain, in press, gives details of this procedure). Figure 4 shows calculated velocities for several representative shell types. All are less than the velocities of modern rapid swimmers. Among the ectocochliates, oxycones have the highest velocity estimates, due to their small drag coefficients. The high stability of nautilicones is the chief reason why they also give high velocity estimates. Serpenticones and cadicones exhibit low velocities because such shells have little stability and high drag coefficients. Fossil ectocochliates appear to have been very slow animals compared to most modern forms. It is unlikely that many were the active, fast-moving predators envisioned by many paleontologists.

PROPULSION

Propulsive output ultimately limits the performance of both animal and machine, and hence is a critical element of design in organic and engineering applications requiring speed. One factor of over-riding importance is the thrust developed by the propulsive system. I determined this for *Nautilus* by removing an animal from its tank and positioning it so that its hyponome was directed toward a vane suspended from an axle. The impact of the jet causes the vane to swing through an arc, the angle of which is proportional to the force of the jet. The animal is held close to the vane to minimize frictional losses to the air and directional change in the jet due to gravity. This technique cannot provide the quality of data familiar to workers on fish locomotion, but it can provide information upon which to base general estimates of performance. In this regard, the present thrust data are consistent with the strain gauge measurements of jet force in *Nautilus* recently reported by Packard et. al. (1980).

Table 1 shows the maximum thrust for a single squirt recorded from about 50 trials for a healthy 890 g female, expressed as thrust coefficient (thrust/total weight). The value indicated for *Nautilus* is more than an order of magnitude less than for the other cephalopods listed in Table 1. This is too great a disparity to attribute entirely to the test apparatus. It would seem that *Nautilus* cannot swim rapidly (Figure 4) mainly because its power plant is incapable of developing the necessary thrust (the high drag coefficient of *Nautilus* is also a factor; Chamberlain 1976).

The chief reason for this situation probably lies in the fact that *Nautilus* simply does not have much propulsive muscle. The mass of the hyponomic and cephalic retractor muscles of the test specimen, determined from autopsy, gives a mass ratio (propulsive muscle mass/total mass) of about 0.1 (see Table 1). Except for *Octopus*, all the endocochliates in Table 1 have mass ratios two to three times higher. The high speeds that characterize cephalopods like *Loligo* (in excess of 100 cm/sec; Trueman & Packard 1968) are due largely to their generous endowment of propulsive muscle. When one recalls that *Octopus* is primarily benthic, with heavily muscled arms for grasping and locomotion over the substrate, and resorts to jet swimming only infrequently, while *Nautilus* is an obligatory swimmer, the disparity in propulsive muscle among cephalopods becomes even more pronounced. The very high mass ratios for trout and dace (Table 1) do not necessarily result in speeds higher than for *Loligo*. The main advantage of the generally better-muscled fish in this respect is to increase their resistance to fatigue and their ability to maintain high sustained speeds.

The weakly-muscled condition of *Nautilus*, and undoubtedly of fossil ectocochliates as well, stems primarily from two causes: 1) retention of the shell as a major feature of adaptive design; and 2) reliance on jet propulsion as the locomotory mainstay. The shell of *Nautilus* is a heavy

structure, and in order to provide near neutral buoyancy, much of the interior must remain empty. Thus, *Nautilus* and other ectocochliates maintain large phragmocones. But in terms of propulsion, the phragmocone is wasted space. It cannot accommodate propulsive muscle, yet it creates additional drag and mass by making the shell larger than it would otherwise be. None of the other animals in Table 1 face the problem of a heavy external shell, so they can pack relatively more propulsive muscle into their bodies.

Sepia is probably very close to the mass ratio design limit for a shelled cephalopod. Its cuttlebone occupies about 22% of its total volume (calculated from data in Denton & Gilpin-Brown 1961), yet *Sepia* has a fairly high mass ratio. In contrast, the shell of *Nautilus* comprises about 30% of the animal's total volume. Many ammonoids had thin shells with relative volumes in the range of *Sepia*'s (Trueman 1941). Thus, in theory, they may have had respectable mass ratios, and been capable of higher velocities than *Nautilus*. Yet, ammonoid retractor muscle scars, where they are known, are generally smaller than those of *Nautilus* (Mutvei 1957, 1964). Moreover, most ammonoids were less stable than *Nautilus* (Raup 1967). These effects combine to make it unlikely that ammonoid locomotive performance was equal to that of *Sepia*, although it is probable that some ammonoids, oxycones in particular (Figure 4), were somewhat better in this regard than *Nautilus*.

Modern engineers hold the jet engine in high regard, but in the organic world, jet propulsion, at least as it is constituted in cephalopods, suffers a serious shortcoming. It requires a large internal space (mantle cavity) to act as a reservoir for the water used in the jet. As in the case of the phragmocone this space is a loss in terms of propulsive muscle. The effect of this factor on performance can be illustrated by considering the exhaust ratios (mass of propellant/total mass) of the animals listed in Table 1. For *Nautilus* this reservoir accommodates a volume of water equal to nearly 20% of the animal's total mass, as measured by having a specimen empty its jet into a graduated cylinder, while for the nektonic endocochliates in Table 1, exhaust ratios are in the order of 50%. Since the thrust of a jet depends in part on the mass of the propellant, these data suggest that *Eledone*, *Loligo*, and *Sepia*, and probably the other endocochliate swimmers they represent, are capable of producing much more thrust/squirt than *Nautilus*. The low value for *Octopus* derives from the fact that it normally uses its well-muscled arms, rather than its jet, as its primary means of locomotion.

Yet, the large mantle cavities, which contribute so importantly to the propulsion of endocochliates, consume the space necessary for accommodating large quantities of propulsive muscle. Because of their reliance on jet propulsion, cephalopods, and especially endocochliates, are caught in a paradox. They need large mantle cavities to provide thrust, but must sacrifice propulsive muscle to reach this goal. Fish have no such problem. They can pack their bodies with muscle as Table 1 shows. Moreover, piscine undulatory propulsion provides much greater propellant volumes, as the data in Table 1 indicate, because undulation acts on the ambient water, which is in effect limitless, not on water held internally.

Propellant velocity is also of interest because it affords a means of evaluating Froude efficiency (useful power/total power), a parameter which describes how effectively the power output of the propulsive muscles is used to drive an animal through the water (see Alexander 1977 for a more complete discussion of Froude efficiency). Froude efficiency is high, and hence useful power is maximized, when propellant velocity is low compared to swimming speed. Equating jet momentum with the momentum of the swimming animal gives a jet velocity for *Nautilus* of about 200 cm/sec, and a Froude efficiency of 0.25 (Table 1). Jet velocity data for *Loligo* and *Sepia* give similar values. It would therefore appear that jet propulsion in cephalopods is limited to Froude efficiencies that are only about half those exhibited by fish. Not only does cephalopod jet propulsion severely restrict the volume of propulsive

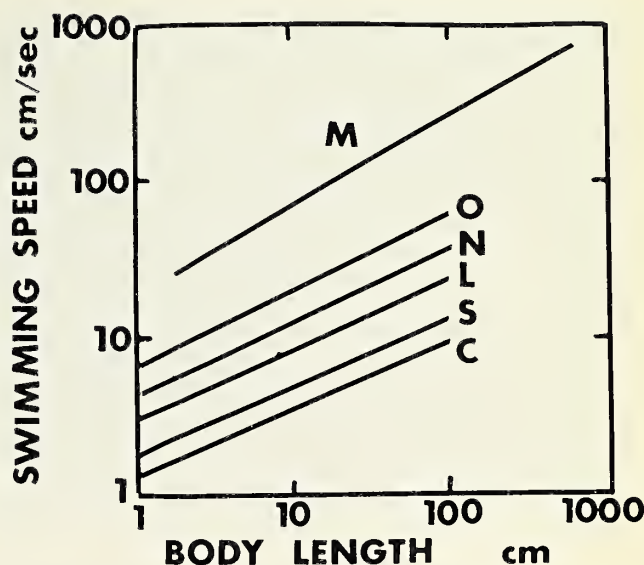


Figure 4. Estimated maximum swimming velocities of fossil cephalopods. Rotational angle of shell = 10° . M - modern rapid swimmers. O - oxycones. N - *Nautilus* (nautilicones). L - lytoceracones. S - serpenticones. C - cadicones. Body length = maximum shell diameter for ectocochliates. Line for modern rapid swimmers is from Chamberlain & Westermann (1976), and is based upon size-velocity data for 29 species of modern nektonic animals - mainly fish and marine mammals, but including *Loligo* and *Dosidicus*. Lines for ectocochliates are based upon specimens described in Trueman (1941); Currie (1958); Raup (1973); and Weaver & Chamberlain (1976); and use drag coefficient data in Chamberlain (1976). After Figure 8, of Chamberlain (in press).

muscle, it also consumes a large part of the power developed by these muscles in an unproductive manner.

EVOLUTIONARY IMPLICATIONS

The foregoing analysis suggests that, in a general way, we can rank cephalopods and fish in terms of sophistication in design of their locomotory systems. *Nautilus*, and presumably fossil ectocochliates, would represent the most primitive level in this hierarchy. Their large, external shells prevent the development of a fine-tuned equilibrium control mechanism, and limits the output of the propulsive system by severely restricting propulsive muscle and mantle cavity volume. Thus, these animals are slow, relatively unmaneuverable swimmers. Endocochliates occupy an intermediate position in the hierarchy. Reduction and loss of the shell, which is the hallmark of endocochliates, has allowed them to fabricate a sensitive system of equilibrium control based on low static stability and compensatory body movements. It has also increased muscle volume and mantle cavity capacity, thereby making endocochliate propulsion much more effective than that of ectocochliates. Fish would seem to occupy the apex of the locomotive ladder. Like ectocochliates, they have an effective system of equilibrium control. But they excel endocochliates in having a propulsive mechanism that maximizes muscle capacity and efficient usage of muscle power.

These ideas suggest the possibility that locomotive adaptation may have played an important role in the evolution of these three groups (see also Packard 1972). Retention of the shell seems to have presented ectocochliates, which appear first in the fossil record, with a unique

adaptive advantage - an effective means of buoyancy control; and a unique, and insurmountable adaptive dilemma - an inherently weak propulsive system.

The evolutionary history of ectocochliates may reflect the interweaving of these two great adaptive themes. Their early success in the Paleozoic may result from the adaptive superiority conferred over contemporary swimmers by buoyancy control, and their demise in the Mesozoic and Cenozoic being the inevitable result of their inability to match the locomotive performance of fish and endocochliates. These groups, although appearing later than ectocochliates, had by this time reached their own solutions to buoyancy control - solutions that did not involve the severe constraints on propulsion deriving from an external shell. In addition, the expansion of the endocochliates in the late Paleozoic and Mesozoic may well have been spurred by the beneficial effect reduction and loss of the shell has on cephalopod propulsive performance. The propulsive superiority of fish over endocochliates may have contributed in an important way to the impressive species diversity of modern fish, and to their apparent dominance of neritic and pelagic realms and large body size, where active swimming is a key to ecologic success.

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FIRST REARING OF *OCTOPUS JOUBINI* ROBSON, 1929 ON MYSIDACEAN AND CARIDEAN SHRIMPS.

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ABSTRACT

Octopus joubini was reared for the first time, from hatching to sexual

maturity, on a diet composed exclusively of live mysidacean and caridean shrimps (*Mysidopsis almyra* and *Palaemonetes pugio*). The octopuses were reared in 150 and 300ℓ closed artificial seawater systems maintained at a temperature of 25°C and a salinity of 35‰. Octopuses were first fed small *Mysidopsis* for 4 to 6 weeks after hatching and then larger *Palaemonetes* for the remainder of the study. An initial group of 137 octopus hatchlings were group-reared for 23 weeks, with 41% survival (56 octopuses) to sexual maturity. The growth of 26 individual

octopuses fed the same shrimp diet was followed closely for 19 weeks, with the animals being weighed at one to two-week intervals. The growth rate during the first four weeks was 6.6% increase in body weight per day. From 4 to 19 weeks growth rates declined to a mean of 2.8% increase in body weight per day. Growth rates and survival were comparable to previous rearing studies using live decapod crabs (*Uca spp.*) and showed that *Mysidopsis* and *Palaemonetes* are reliable alternatives for rearing *O. joubini*.

INTRODUCTION

The pygmy octopus, *Octopus joubini* Robson, 1929 has been reared in the laboratory using open (flow-through) and closed (recirculating) seawater systems (Boletzky and Boletzky, 1969; Thomas and Opresko, 1973; Bradley, 1974; Opresko and Thomas, 1975; Forsythe, 1980; Forsythe and Hanlon, 1980). During the past ten years the culture technology for rearing *O. joubini* and other large-egg octopuses has increased significantly, and the feasibility of providing live octopuses for research through laboratory culture continues to improve. The work of Thomas and Opresko (1973) and Opresko and Thomas (1975) provides an excellent example of open-system culture methods while we recently reported (Forsythe and Hanlon, 1980) on refined methods for rearing *O. joubini* in moderate numbers in closed seawater systems. With reliable culture systems now available, food has become the principal consideration in octopus culture and thus far all successful culture work has relied upon diets of live decapod crabs. Alternate food organisms that produce good growth and survival are needed since few coastal areas have reliable supplies of easily collected live crabs in sufficient numbers year-round. This work represents the first culture of *O. joubini* on a diet composed exclusively of live mysidacean and candean shrimps (*Mysidopsis almyra* and *Palaemonetes pugio*). These shrimps are abundant estuarine organisms that can be collected year-round in Galveston Bay, even in the coldest winter months. Adult *Mysidopsis* have a total length of 6 to 9 mm and are an ideal size for feeding to octopus hatchlings and very young octopuses. The *Palaemonetes* are slightly larger ranging from 1 to 5 cm total length and are suitable for feeding to older juvenile and adult *O. joubini*.

MATERIALS AND METHODS

The octopuses used in this study were second generation descendants of wild-caught *Octopus joubini*. They were reared in 150 and 300 l closed seawater systems using Instant Ocean^(R) artificial sea water (Forsythe and Hanlon, 1980). The aquaria were subject to indirect sunlight that provided a natural light cycle, and culture system temperatures and salinities were maintained at 25°C ($\pm 1^\circ\text{C}$) and 35 ‰ (± 1 ‰). *Mysidopsis* and *Palaemonetes* were collected weekly with small push nets, beam trawls or 3 m seine nets in shallow water (1 m) and transported to the laboratory. It was necessary to acclimate the *Mysidopsis* to the temperatures and salinities of the culture systems prior to adding them, whereas the *Palaemonetes* required no acclimation.

The octopuses were both group and individually reared. For group rearing, freshly hatched octopuses were transferred to a shallow plastic tray tank (76 x 30 x 10 cm) that was connected to the main culture system by a pump and return siphons. Water depth was maintained at 4 to 5 cm and squares of plastic artificial grass were inverted and floated in the tray tank to provide shelter for the hatchlings. The proximity of the grass to the tank bottom allowed individual octopuses to observe and capture prey easily. Live *Mysidopsis* were supplied *ad libitum* in the tray tank and uneaten food remains were removed daily. As the octopuses grew, small numbers of the larger *Palaemonetes* were introduced and as the octopuses reached a weight of 0.5 g these shrimps completely replaced the



Figure 1 A 20-day-old *Octopus joubini* hatchling (mantle length 8 mm) with 4 to 6 *Mysidopsis* in its web. Note the relative size of the mysids to the octopus hatchling.



Figure 2 An 8-week-old *Octopus joubini* (mantle length 13 mm) feeding on two *Palaemonetes*, one of which is completely wrapped in the arms. The visible shrimp is 25 mm long.

Mysidopsis as food organisms. As the octopuses approached adult size, the population was moved to a larger glass tray tank (90 x 45 x 20 cm) with a water depth of 7 to 8 cm. Mortalities and additions of new hatchlings were recorded throughout the experiment to estimate survival.

To determine precise growth rates, 26 octopuses of known age were reared in separate growth chambers suspended in the culture systems. Like the group-reared octopuses, these individual animals were fed first on an *ad libitum* diet of live *Mysidopsis* and later on live *Palaemonetes*.

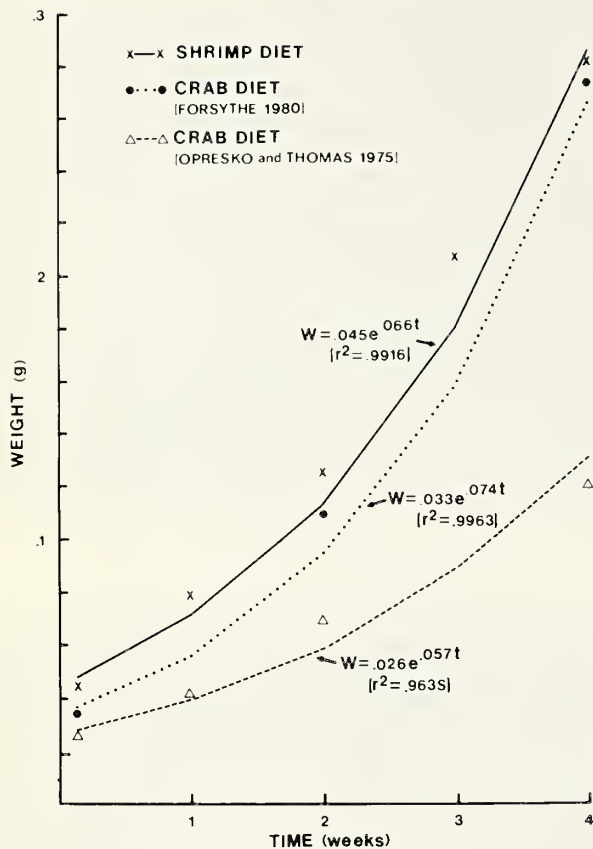


Figure 3. Growth of *Octopus joubini* on shrimp and crab diets from hatching to 4 weeks. The growth curves are derived from the given equations with t = age in days. Data points are actual mean weights used in deriving the equations. Equation and growth curve for Opresko and Thomas (1975) calculated from their published data.

The octopuses were weighed at hatching, and at seven-day intervals for the first seven weeks, and at 14-day intervals for the next 12 weeks. Prior to weighing, the animals were narcotized in a 1% solution of ethyl carbamate (Urethane) in sea water for approximately 90 seconds. Weights were recorded to the nearest 10 mg on an electronic balance. The mean weight for the group was determined after each weighing and these values were used in calculating the following values. Mean instantaneous growth rates were calculated as per cent increase in body weight per day using the equation:

$$\text{Growth rate} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \times 100$$

where W_2 = final weight, W_1 = initial weight, t_2 = age in days at W_2 and t_1 = age in days at W_1 (Wells and Wells, 1970). Equations describing different periods of growth were derived from growth data using a least-squares linear regression.

RESULTS AND DISCUSSION

Live *Mysidopsis* and *Palaemonetes* proved to be reliable food organisms from both a collecting and rearing standpoint. Both types of shrimp

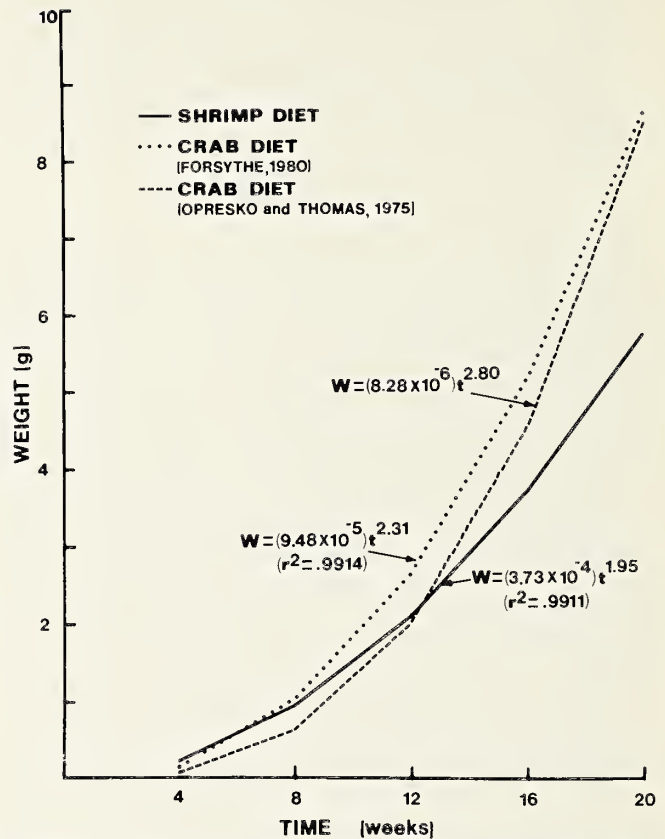


Figure 4. Growth of *Octopus joubini* on shrimp and crab diets from 4 to 20 weeks. The growth curves are derived from the given equations with t = age in days.

could be collected in large numbers throughout the winter when small live decapod crabs were scarce. Live *Mysidopsis* were the sole food organisms supplied to the young octopuses for the first 4 to 6 weeks after hatching (Figure 1). This diet was well accepted by the octopuses with hatchlings beginning to feed within 24 to 36 hours after hatching. They fed actively during the first month and as the octopuses grew, individuals were often seen with up to 6 to 7 mysids in their arms. These mysids are slow swimmers with a relatively weak escape response and possess no large chelipeds with which to inflict damage on attacking octopuses. Very small octopus hatchlings were easily able to capture and subdue the mysid shrimps without injuring themselves.

As the octopuses grew to a size of 0.3 to 0.5 g, the larger *Palaemonetes* were gradually introduced into the shallow tray tank where the group-reared octopuses were still feeding on mysids. This allowed the smaller octopuses to feed on mysids while larger octopuses began feeding on the larger food organisms. All the *Palaemonetes* were eaten the first time they were introduced. (Figure 2). The individually reared octopuses also showed quick acceptance of *Palaemonetes*.

Survival on the shrimp diet was the highest we have yet achieved with *Octopus joubini* in our small closed seawater system. A total of 137 *O. joubini* hatchlings were added to the tray tank during the first six weeks of the group rearing experiment (only 9 hatchlings were added during weeks 5 and 6). Survival to six weeks was 54% (74 octopuses) while survival to 23 weeks was 41% (56 octopuses), at which time most of the population had reached sexual maturity. Survival from hatching to

sexual maturity was approximately twice the survival we had achieved group rearing *O. joubini* in similar culture systems on a live crab diet (Forsythe and Hanlon, 1980). The low survival on the crab diet was a result of very high mortalities during the first 30 days when it was difficult to supply a sufficient number of small crabs. We have been able to greatly improve hatchling survival during this period by using mysids. Thomas and Opresko (1973) reported survival of 54% to six weeks and 44% to 20 weeks for 95 *O. joubini* reared on live crabs (*Uca*) in open, flow-through seawater systems. Our results with shrimp are nearly identical.

Octopuses fed exclusively on shrimp grew from a mean weight at hatching of .045 g (26 animals) to a mean weight at 19 weeks of 6.59 g (11 animals). Analyses of the growth data revealed that octopuses reared on live shrimps showed the same pattern of growth at similar rates as those reared on live crabs (Figures 3 and 4). *O. joubini* show fast exponential growth the first four weeks, followed by slower logarithmic growth to maturity (Opresko and Thomas, 1975; Forsythe, 1980). In our observations, the growth rate during the first four weeks was 6.6% increase in body weight per day. Growth was best described ($r^2 = .9916$) by the exponential equation: wet weight (g) = $.045e^{.066t}$, where t = age in days. Growth from 4 to 15 weeks declined to 3.2% increase in body weight per day, and from 15 to 19 weeks it further declined to 2.6%. The growth curve during this 15-week period of logarithmic growth was best fit ($r^2 = .9911$) by the equation: wet weight (g) = $(3.73 \times 10^{-4})t^{1.96}$.

Figures 3 and 4 compare equation-derived growth curves for *O. joubini* reared on shrimp or crab diets. Our growth rate of 6.5% body weight per day over this period was within the range of 7.4% (Forsythe, 1980) and 5.6% (Opresko and Thomas, 1975) obtained on the crab diets. Growth from 4 to 20 weeks (Figure 4) was good but slower than that of the crab diets during the last half of the growth period. The overall mean daily growth rate on the shrimp diet was 2.8% increase in body weight per day compared to 3.3% (Forsythe, 1980) and 4.0% (Opresko and Thomas, 1975) for the crab diets.

Our survival and growth experiments show that live mysidacean and caridean shrimps are reliable alternatives to live crabs for rearing *O. joubini*. These shrimps are often abundant year-round in coastal areas

and are easy to collect and hold in large numbers. These findings may be useful in laboratory culture of large-egg benthic octopods, since supplying sufficient numbers of suitably sized food organisms, particularly during the first few weeks after hatching, is essential for the successful culture of *Octopus*.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. Sigurd von Boletzky for critically reviewing the manuscript. We also thank Joe Hendrix, Mark Krejci and Phil Turk for their assistance in collecting shrimps throughout the study and Sharon Burton for typing the various drafts of the manuscript. This work was supported in part by the Marine Medicine General Budget account #7-11500-765111 of the Marine Biomedical Institute.

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CHANGES IN SHELL MORPHOLOGY OF POST-LARVAL *TRIDACNA GIGAS* LINNE (BIVALVIA: HETERODONTA)

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Details of embryology and early post-larval development have been studied in several species of *Tridacnidae* (La Barbera, 1974, 1975; Jameson, 1976; also see Heslinga, 1979). No detailed reports have been published concerning the development of *Tridacna gigas*, the largest species, although Heslinga (ibid.) listed an unpublished report on that subject (viz., Beckvar, N., and G.A. Heslinga [1978]).

Nancy Beckvar, formerly of the Micronesian Mariculture Demonstration Center (MMDC) in Palau, kindly provided several shells of *T. gigas*, 2 to 5 months of age, for my examination (see fig. 1). When I informed her that I wished to publish on the specimens, she indicated that MMDC had no such plans and gave permission. Unfortunately shells only survived in shipment and observations on animals of these ages are still lacking. For comparison with the post-larval specimens, I selected at random 9 more mature specimens.

In the first age group of 12 specimens, 2-3 months old, maximum lengths range from 1.0 to 1.8 mm; the angle formed by the hinge line-ventral margin varies from 35-63°. In the second group of 12 speci-

mens aged 3-4 months, shells range from 1.6 to 3.0 mm length; the same angle varies from 64-90°. The third group of 5 specimens aged 4-5 months, range from 2.8 to 4.8 mm length; their angle varies from 85-100°. The 9 mature specimens range from 5.2-27.2 cm in length; their angle varies from 131-150° (see fig. 2).

From the above admittedly sparse data certain growth tendencies may be seen during the first few months of post-larval life (see fig. 3). Young *T. gigas* begin life with a wedge-shaped shell rather than the broadly fan-shaped outline characteristic of older individuals. At 4-5 months of age this has changed and the angle formed by the hinge line and ventral margin may exceed 90°. Older individuals measuring from 5.2 to 9.3 cm, probably range in age from 1-2 years (Rosewater, 1965, p. 348). The angle of these shells varies from 131-150°, and other considerably larger shells do not significantly exceed the larger angle. Shells of approximately one year of age, therefore, exhibit a mature configuration.

It has been known for some time that certain species of *Tridacna* have an early post-larval shell that is wedge-shaped and exhibits an angle less than 90° (see Stasek, 1962 p. 9; Rosewater, 1965, fig. 268). Stasek (ibid.) showed this for *T. elongata* (= *T. maxima*), and also predicted from his admittedly meagre data that the angle would increase markedly due to growth along the ventral margin which pushes the hinge margin upwards and over to its more mature orientation. La Barbera (1975, p. 78) confirmed the tendency for growth to proceed most rapidly from the ventral margin in another species, *T. squamosa*. The same growth pat-

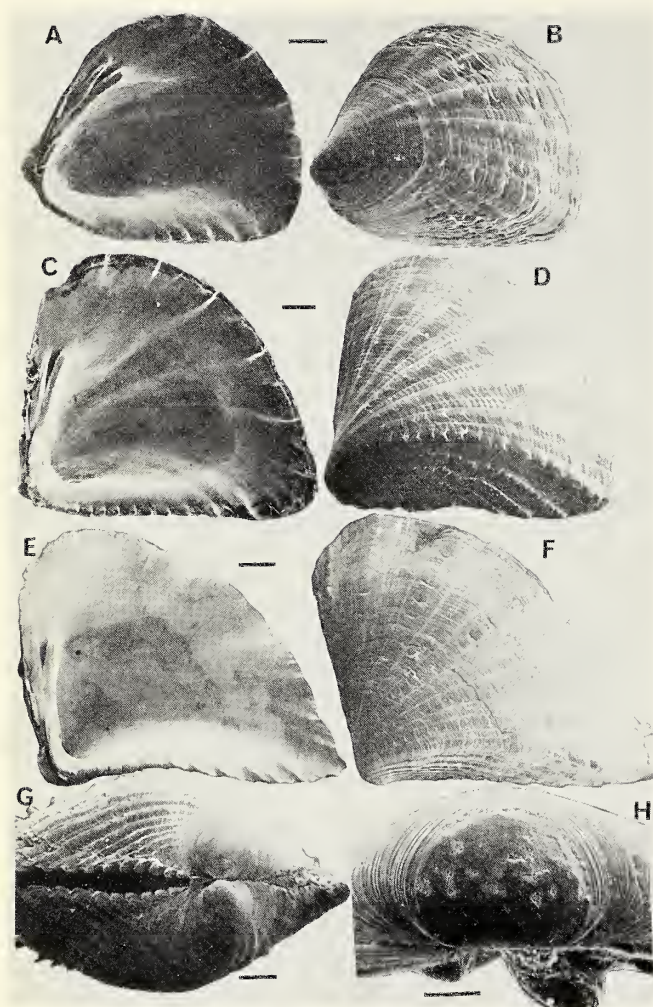


Figure 1. Scanning Electron micrographs of post-larval *Tridacna gigas* shells (USNM 781985, from Koror, Palau Islands). A. Interior, right valve; B. Exterior, left valve; 2-3 month stage, 1.8 mm length, angle 63° ; note poorly developed byssal area. Bar = $200\mu\text{m}$, 45X.

C. Interior, right valve; D. Exterior, left valve; 3-4 month stage, 2.5 mm length, angle 82° ; note sculpture and narrow, tubular spines characteristic of *T. gigas*. Bar = $300\mu\text{m}$, 30X.

E. Interior, right valve; F. Exterior, left valve; 4-5 month stage, 4.8 mm length, angle 100° . Bar = $600\mu\text{m}$, 12X.

G. Ventral view 4-5 month stage; note well developed byssal orifice plicae. Bar = $300\mu\text{m}$, 30X.

H. Umbonal area, right valve of 2-3 month stage showing outline of prodissococonch and hinge teeth. Bar = $50\mu\text{m}$, 300X.

tern occurs in *T. gigas*, and in the present study, the change from a wedge-shaped to fan-shaped outline is shown to occur during the second to fifth month of post-larval life.

The change in shell angle during early post-larval life may be due to several causes. It could be an example of the "Recapitulation Theory", i.e., individuals in their development, or ontogeny, pass through some of the same stages shown during their evolution or phylogeny. Since it is generally agreed that Tridacnidae evolved from a more "normal" car-

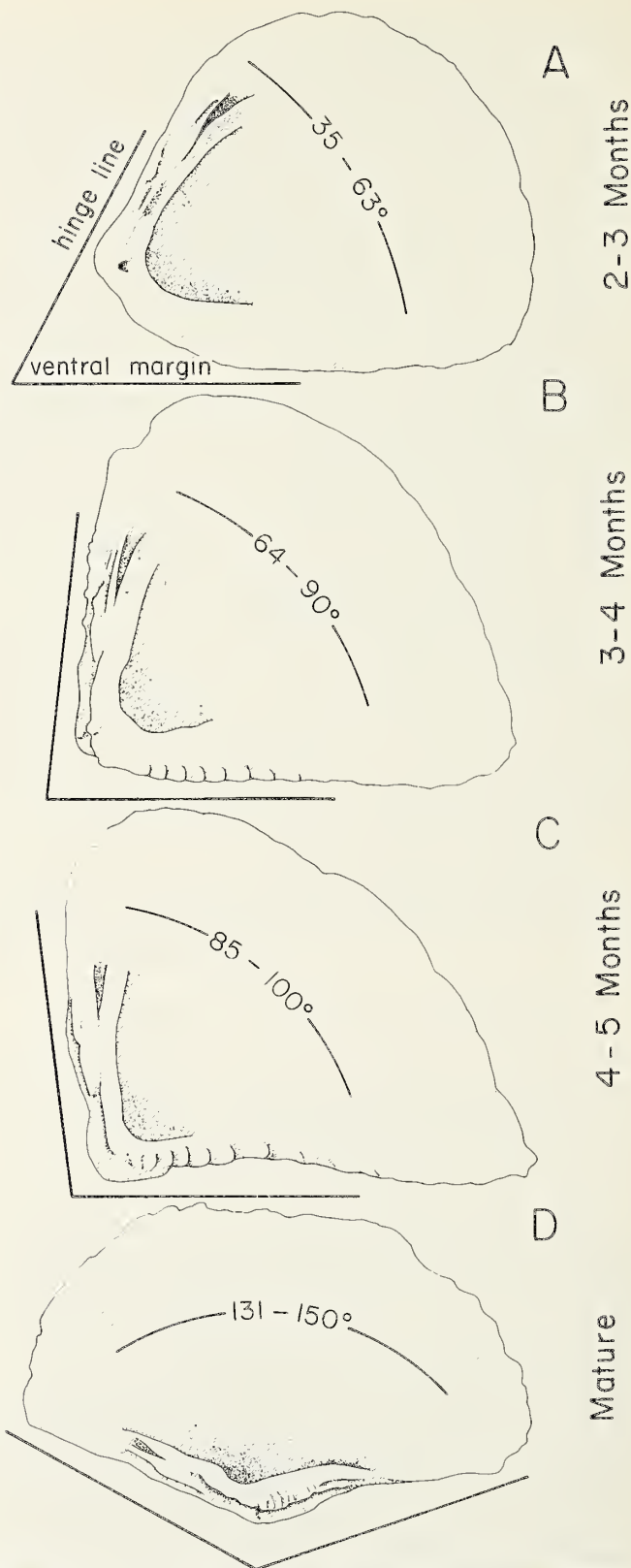
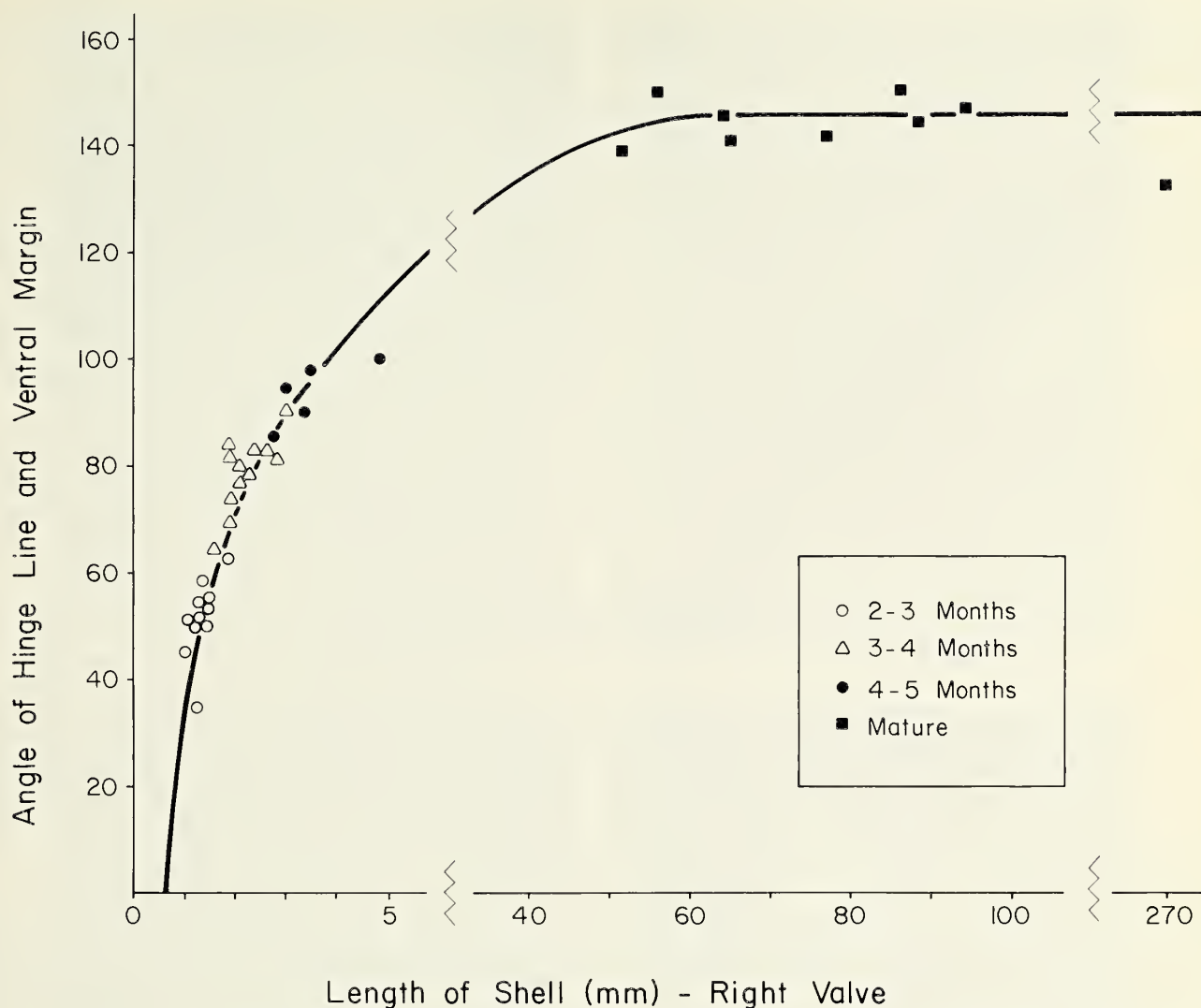


Figure 2. A-C. 2-5 month post-larval shells of *Tridacna gigas* (USNM 781985, from Koror, Palau Islands); D. Mature shell (USNM 747101, "Australia"). observed ranges of hinge line-ventral margin angles are shown.



while projects as those being carried out at the Micronesian Mariculture Demonstration Center in Palau should be encouraged and efforts expanded to increase these vanishing resources.

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An Ultrastructural Study of the Salivary Gland of the mud-snail, *Ilyanassa obsoleta*

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ABSTRACT

The morphology of the salivary gland and duct of *Ilyanassa obsoleta* was described at the ultrastructural level using transmission electron microscopy. Three cell types, Type I granular secretory cells, Type II granular secretory cells and mucous cells have similar morphology. All three have well developed Golgi complex and granular endoplasmic reticulum. Type I secretory granules are present as distinct vacuoles and are the most electron dense. Type II secretory granules exhibit a high degree of fusion to form large vacuoles and are less electron opaque than Type I granules. The mucous cell vacuoles have the lightest density and the greatest degree of fusion between vacuoles. The secretory process is similar for the three cell types. Secretory product which normally fills the cell is expelled upon stimulation of the gland during feeding by the snail, and transported by the ciliated salivary duct cells. Starvation results in reduced amounts of glycogen, less dense cytoplasm, reduced number of cilia and microvilli, and altered and degraded secretory granules.

Key Words: Ultrastructure - Salivary gland - *Ilyanassa obsoleta*

INTRODUCTION

The salivary gland is a secretory structure located alongside the esophagus in many molluscs. The gland usually consists of one or two lobes of the acinar type (Hyman, 1967); (Fretter and Graham, 1962). Recent studies of these glands in the gastropods have dealt with neural control of salivation (Kater, 1974; Prior and Gelperin, 1977; Kater et al., 1978) and morphological studies. Ultrastructural studies have been conducted in *Helix aspersa* by Quattrini (1967) who described 2 secretory cell types; *Lymnaea stagnalis* with 9 secretory cell types (Boer et al., 1967); *Agriolomax reticulatus* with 10 cell types (Walker, 1970) and

Limax maximus with 4 cell types (Beltz and Gelperin, 1979).

The present study was conducted to characterize the salivary gland cell types of *Ilyanassa obsoleta*. A feeding experiment with fed and starved groups of *Ilyanassa obsoleta* was also conducted. The effects of starvation on the ultrastructure of the salivary gland were compared to the salivary glands of the fed group. Terms used to designate cell types of the salivary gland are from the light microscopy work of Brown (1969).

MATERIALS AND METHODS

Adult individuals of *Ilyanassa obsoleta* were collected in August 1979 at lowtide from Clambank Creek, Baruch Plantation, Georgetown, South Carolina and kept in aerated and filtered aquaria containing 30% seawater at 20°C + 1°. Snails were divided into three groups of 33 snails per group. One group was fed shrimp, the second lettuce, and both were allowed to feed daily for at least two hours, after which most feeding activity ceased. The feeding experiment was conducted for four months. The third group was not fed at all during the four month period. Several times during the four months and at the completion of the experiment, salivary glands were dissected from unnarcotized snails.

Transmission Electron Microscopy

Pieces of salivary gland and salivary duct were fixed in 2% glutaraldehyde in .05M sodium cacodylate seawater buffer pH 7.4, for 2 hours, postfixed in 1% buffered osmium tetroxide 1 hour, dehydrated in an ethanol series and embedded in Spurr standard medium (Spurr, 1969). Thin sections were cut with a diamond knife on a Sorvall MT-2B ultramicrotome. Sections were placed on coated copper grids 150 mesh and stained with 4% uranyl acetate (Watson, 1958) and lead citrate (Reynolds, 1963). Sections were examined with a Zeiss EM-9 operated at 60Kv. and a JEOL 100-B operated at 80Kv.

Scanning Electron Microscopy

Material for SEM was fixed and post-fixed as described above. After ethanol dehydration specimens were passed through a freon series and

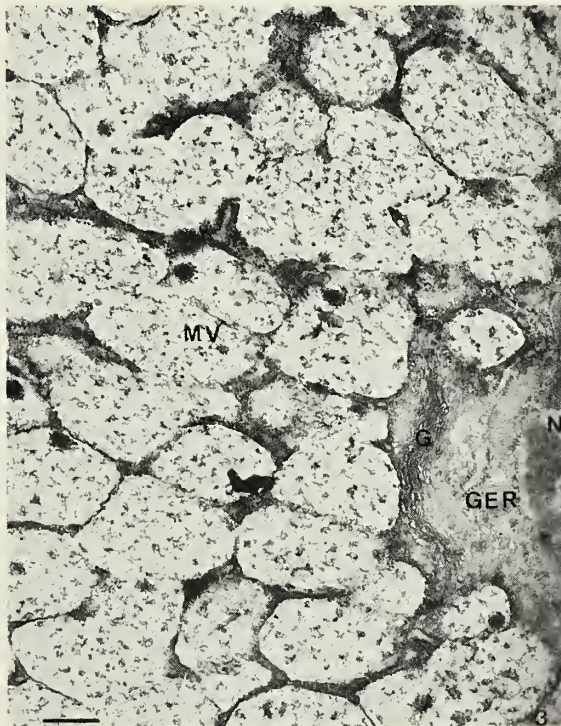
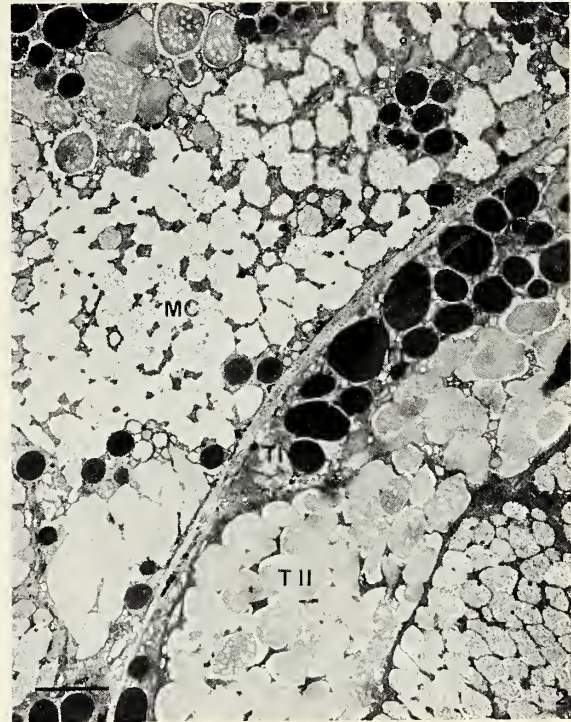
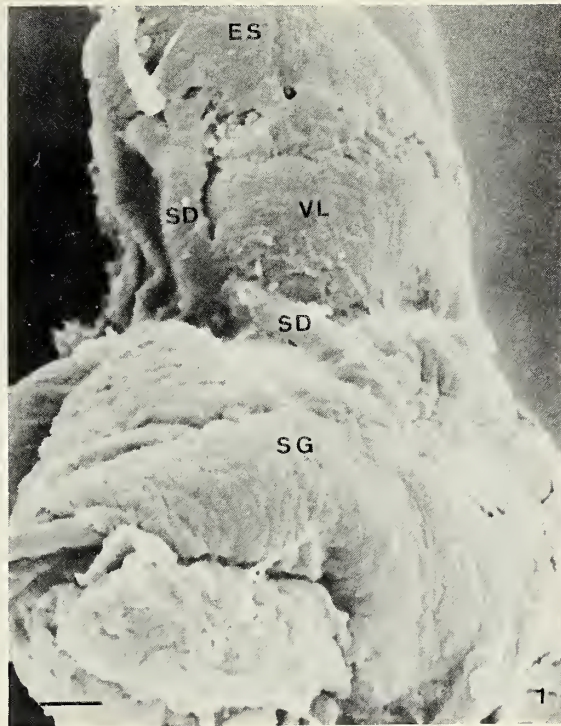


Fig. 1. Scanning electron micrograph of left salivary gland lobe (SG), valve of Leiblein (VL), esophagus (ES), and salivary duct (SD). Bar = 100 μ

Fig. 2. Transmission electron micrograph of a single salivary gland acinus. Type I granular secretory cell (TI), Type II granular secretory cell (TII), and mucous cell (MC). Bar = 3 μ

Fig. 3. Filled mucous cell showing displacement of organelles by secretory vacuoles. This condition exists in all three cell types.

Mucous vacuoles (MV), Golgi complex (G), nucleus (N), granular endoplasmic reticulum (GER). Bar = 1 μ

Fig. 4. Salivary gland fixed during feeding. Formation of Type I secretory granules. Granular endoplasmic reticulum (GER), Golgi complex (G), nucleus (N), condensing vacuole (CV), mature Type I secretory granule (MTI), multivesicular body (MB), electron dense body (ED). Bar = 1 μ

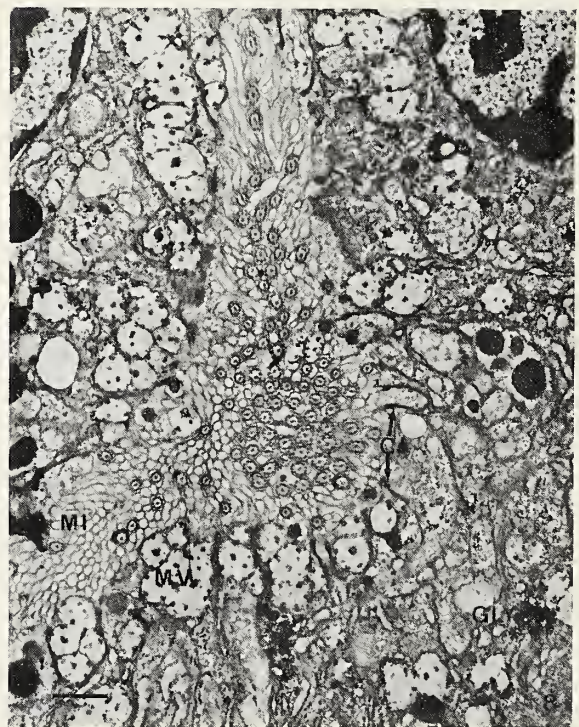
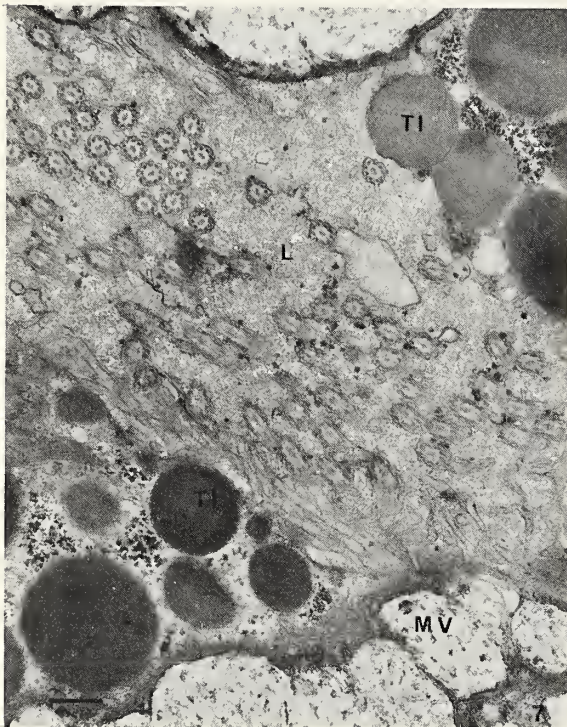
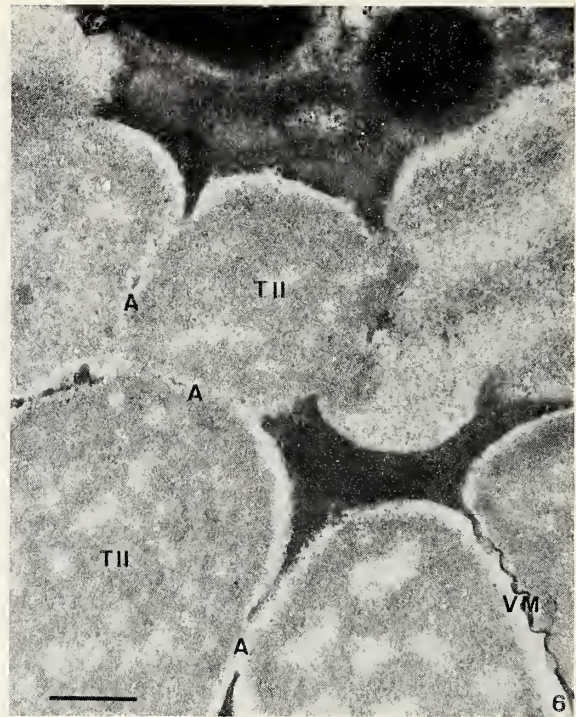
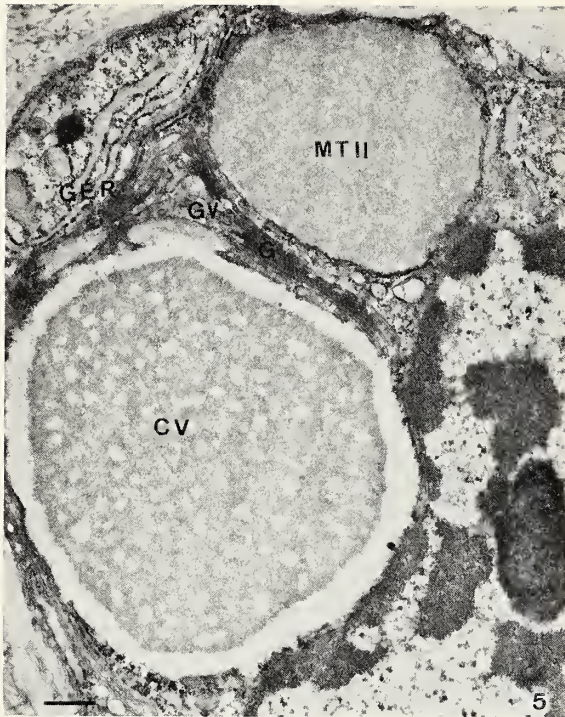


Fig. 5. Formation of Type II secretory granules. Golgi complex (G), granular endoplasmic reticulum (GER), almost mature condensing vacuole (CV), mature Type II secretory granule (MTII), Golgi vesicles (GV). Bar = 1μ .

Fig. 6. Type II secretory granules fusing. Notice "rippling" effect of the membranes and indistinct vacuolar membrane. (A.) Bar = $.5\mu$

Fig. 7. Type I secretory granules being expelled into lumen of ductule. Note extensive degree of fusion of mucous vacuoles. Lumen of ductule (L), Type I secretory granule (TI), mucous vacuoles (MV). Bar = 5μ .

Fig. 8. Expulsion of mucous vacuoles into lumen of ductule. Mucous vacuole (MV), lumen of ductule (L), cell junctions (CJ), glycogen granules (GLY), microvilli (MI). Bar = 1μ

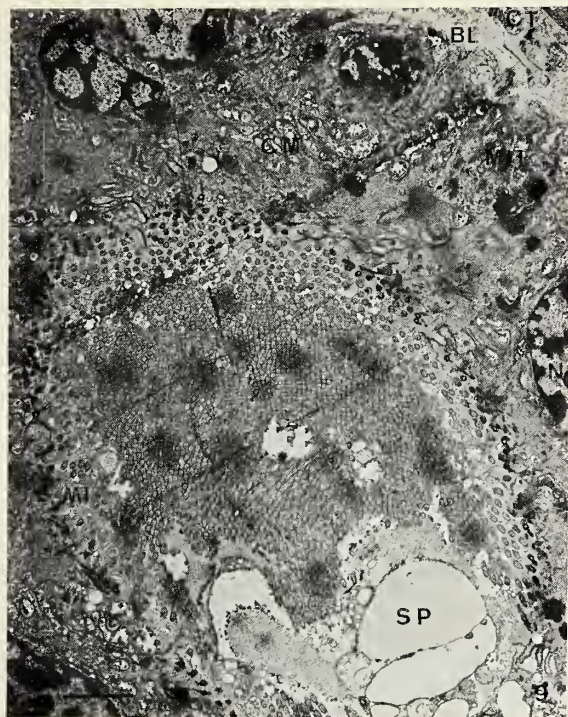


Fig. 9. Cross section of salivary duct with secretory product being transported by cilia. Nucleus (N), cilia (*), secretory product (SP), mitochondria (MIT), cell membrane (CM), microvilli (MV), basal lamina (BL), connective tissue (CT). Bar = 3μ

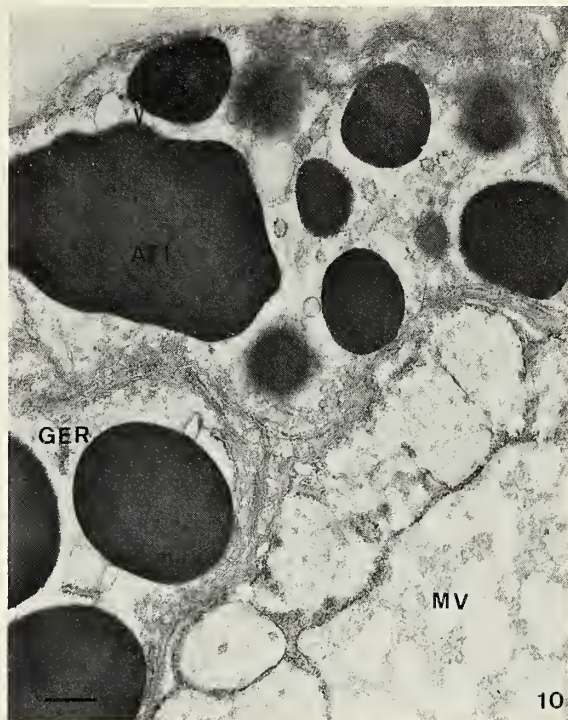
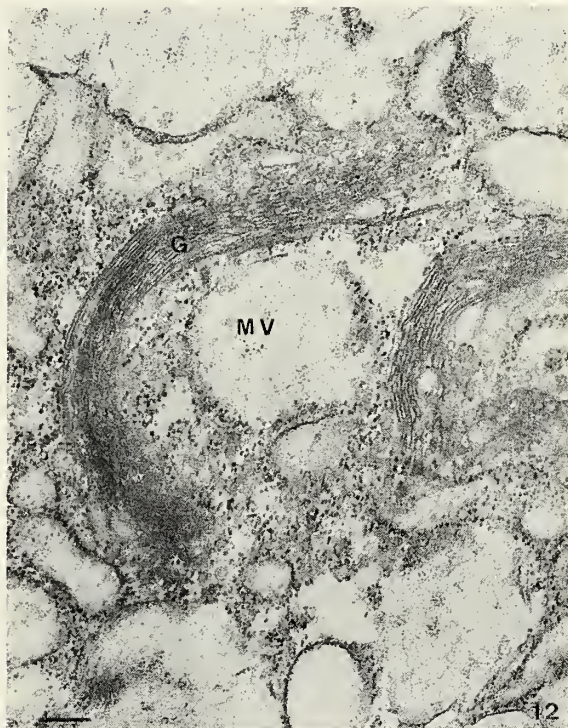


Fig. 10. Salivary gland of starved specimen. Notice altered Type I secretory granule and fusion of mucous vacuoles into exceptionally large mass. Cytoplasm is not very dense and GER is reduced. Altered Type I granule (ATI), mucous vacuoles



(MV), granular endoplasmic reticulum (GER), vesicles (V). Bar = $.5\mu$

Fig. 11. Degrading Type I secretory granule. Degrading Type I granule (DTI). Bar = $.25\mu$

Fig. 12. An indistinct mucous vacuole near Golgi cisternae. Golgi cisternae appear empty. Mucous vacuole (MV), Golgi cisternae (G). Bar = $.25\mu$

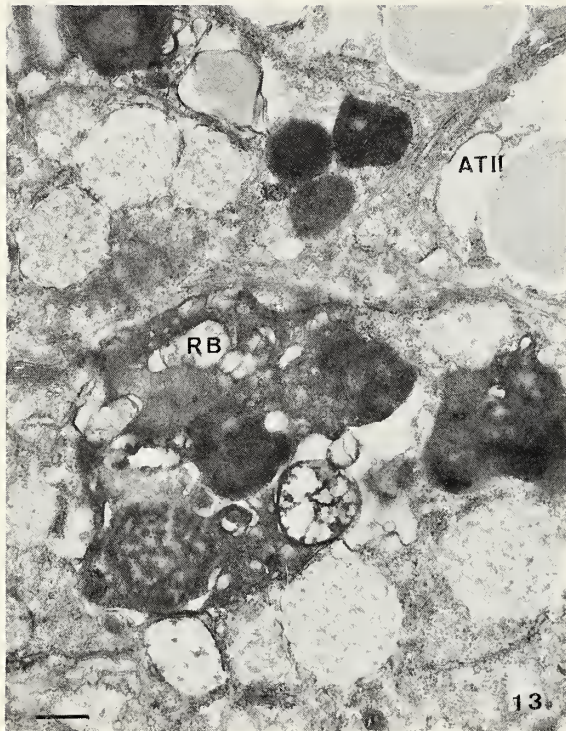


Fig. 13. Mucous cell with possible residual body and altered Type II granules: residual body (RB), altered Type II granules (ATII). Bar = 1μ



Fig. 14. Salivary duct of starved specimen. Lightly staining cytoplasm and lack of glycogen granules. Reduction in number of microvilli and cilia. Lumen of duct (L), cilia and microvilli (*), altered cytoplasm (CYT). Bar = 2μ

critical point dried in an Omar SPC-900 critical point drying apparatus. The pieces were mounted on aluminum stubs with Duco cement and gold coated on a Hummer Sputter coater operated at 10 milliamperes at 175 millitorr for 10 minutes. The samples were viewed with a JEOL SMU-3 operated at 25Kv.

RESULTS

The salivary gland is a whitish lobular structure (Fig. 1). The gland consists of two separate lobes which are attached dorsally to the Valve of Leiblein located between the anterior esophagus and midesophagus and connected to each other by connective tissue. A salivary duct originates from each lobe and extends anteriorly along the esophagus to the buccal cavity. The gland is composed of three types of columnar epithelial cells, Type I granular secretory cell, Type II granular secretory cell and mucous cell. In all cell types the nucleus with a nucleolus is located basally. The well-developed Golgi complex is located laterally or ventro-laterally to the nucleus. Extensive (GER) granular endoplasmic reticulum is present. Glycogen rosettes are distributed throughout the cell. Mitochondria are oval to oblong in shape. Organelles are seen in material fixed during feeding with secretory granules filling central and apical regions of the cell. When not actively feeding, secretory product fills the cell displacing the organelles (Fig. 3). No differences were observed between the separate fed groups nor between the fed groups and field specimens. Observations of the starved group follow results of the fed group.

I. Fed Group

1. Type I granular Secretory Cell

GER cisternae are relatively swollen with material which stains to a medium density (Fig. 4). Golgi vesicles can be seen budding off the Golgi cisternae. Vacuoles are formed along the maturing surface of the Golgi complex. Lightly staining vacuoles with flocculent material are seen near the Golgi complex. Electron opaque vacuoles occur apically of the lightly staining vacuoles. Most of the granules of the Type I cell are discrete vacuoles and only occasionally are fused granules observed (Fig. 7). Multivesicular bodies and electron dense bodies are present (Fig. 4).

2. Type II Granular Secretory Cell

Morphology of the Type II cell is similar to the Type I cell. Initial formation of vacuoles of the Type II cell is similar to that of the Type I cells (Fig. 5). Granules of Type II cells are more electron lucent than Type I granules. Type II granules undergo a higher degree of fusion forming larger vacuoles (Fig. 6). As granules fuse the membranes become indistinct or nipped. The resulting larger vacuoles are more electron lucent than granules not yet fused.

3. Mucous Cell

Ultrastructure of the mucous cell and formation of the mucous vacuoles is similar to Type I and Type II cells described above. Two differences are observed in the mucous cells. Fusion of mucous vacuoles is more extensive than seen for Type II granules (Fig. 7 and Fig. 8). Within the mucous vacuoles electron dense areas are scattered in the vacuoles with filaments radiating outward. Secondly, glycogen granules are present as large clumps (Fig. 8).

4. Salivary Duct

The salivary duct is composed of a single layer of cuboidal epithel-

ium. A thin basal lamina and a loose network of connective tissue fibers surrounds the duct (Fig. 9). Nucleus and mitochondria are located basally. GER and Golgi complex appear less developed than in the salivary gland cells. Glycogen granules are present in large amounts. There is interdigitation of the apical halves of the lateral cell membranes (Fig. 9). The apical surface possesses microvilli and cilia in large numbers. Cilia and microvilli also extend into the lumen of ductules of the acini (Fig. 7 and Fig. 8). Salivary duct fixed during a feeding period had large amounts of secretory product in the lumen. Secretory product is membrane bound and stains to various densities. Degenerating mitochondria, vesicles and cellular debris are observed in the lumen along with the secretory product (Fig. 9). During secretion the cell junctions of the salivary gland cells are clearly seen (Fig. 8).

II. Starved Group

In all three secretory cell types the cytoplasm is less dense. Few glycogen granules are present and GER and Golgi complex is less developed than in the fed group (Fig. 10 and Fig. 11). Type I granules exhibit an irregular shape. Vesicles are seen along the surface of the Type I granule (Fig. 10). Although not seen frequently some Type I granules were in an apparent state of degradation (Fig. 11). In mucous cells fusion of mucous vacuoles into an exceptionally large mass occurred (Fig. 10). Mucous vacuoles close to Golgi cisternae appeared indistinct (Fig. 12). A possible residual body was frequently observed in starved mucous cells (Fig. 13). There is an apparent degradation of Type II granules resulting in pockets devoid of secretory material. Most Type II granules appeared unaffected (Fig. 13). Salivary duct cells have lightly staining cytoplasm. The amount of glycogen granules was reduced. The number of microvilli and cilia was greatly reduced (Fig. 14).

DISCUSSION

The salivary gland of *Ilyanassa obsoleta* is similar to that of other molluscs in the types of secretory granules. The Type I secretory granule has a similar staining characteristic and morphology to the Type IV granules described in *Limax maximus* by Beltz and Gelperin (1979) although the cells in *L. maximus* possess cilia and the Golgi complex and GER are less developed. The Type I cell of *I. obsoleta* does not have cilia and has well developed GER and Golgi complex.

The Type II secretory granule can be compared to the granules reported in the Type III cells of *L. maximus* (Beltz and Gelperin, 1979), the granular cell of *Agriolimnaea reticulatus* (Walker, 1970) and the rat parotid cell (Hand, 1972). The cells of *L. maximus*, *A. reticulatus* and the rat parotid cells have microvilli and/or cilia, while the Type II cells of *I. obsoleta* do not.

The formation of secretory granules in Type I and Type II cells of *I. obsoleta* is similar. A series of vacuoles suggesting different phases of maturation of the vacuoles have been observed in *I. obsoleta* (Fig. 4 and Fig. 5). Initial formation of the vacuole occurs along the maturing surface of the Golgi cisternae. Vacuoles near the Golgi complex stain lightly and have flocculent material and appear to be recently separated from the Golgi cisternae. These granules are similar to the condensing vacuoles reported in rat parotid cells (Hand, 1972 and Pinkstaff, 1980). The condensing vacuole in Type I cells matures to an electron dense Type I granule (Fig. 4). Condensing vacuoles in Type II cells mature to a medium density granule (Fig. 5).

The vacuoles of the mucous cell of *I. obsoleta* are similar to those of the mucocyte I cell reported by Boer *et al.* (1967) in *Lymnaea stagnalis*. The mucous vacuoles of *I. obsoleta* also show close similarity to the vacuoles in mucous cells of the mandibular gland of the Australian brush tail possum (Blood, *et al.*, 1977).

The histochemical studies of Boer *et al.* (1967) and Walker (1970) suggest that the secretory granules reported have a glycoprotein composition and the mucin produced is an acid mucopolysaccharide. Similar findings are reported for rat parotid cells (Pinkstaff, 1980). The histochemical results reported by Brown (1969) for *I. obsoleta* show the Type I and Type II secretory granules to be a glycoprotein and the mucin of the mucous cell is an acid mucopolysaccharide.

The mucous cell of *I. obsoleta* does not have microvilli or cilia. Microvilli are present in the mucous cells of *L. stagnalis* (Boer *et al.*, 1967), *A. reticulatus* (Walker, 1970) and *L. Maximus* (Beltz and Gelperin, 1979).

The salivary duct cells are similar to those in *L. stagnalis* (Boer *et al.*, 1967) and *Helix aspersa* (Quattrini, 1967) having both microvilli and cilia and a cuboidal shape. Extensive interdigitation of the basal and lateral plasma membrane does not exist in *I. obsoleta* to the extent reported for *H. aspersa* (Quattrini, 1967), *A. reticulatus* (Walker, 1970) and *L. maximus* (Beltz and Gelperin, 1979). The presence of microvilli and extensive interdigitation of basal and lateral plasma membranes suggests a role in modifying the saliva through water or ion transport (Kendall, 1969; Oschman and Berridge, 1970). The extent of these features in the salivary duct cells of *I. obsoleta* is reduced. If any modification of the saliva occurs in *I. obsoleta* it is probably to a lesser degree than what is proposed for other molluscs in the studies cited above.

The effects of starvation become apparent over a period of 4 months. There is a reduction in the amount of glycogen granules, cytoplasm is less dense and a reduction in number of microvilli and cilia along the surface of the secretory duct cell. In the salivary gland cells the secretory granules are altered; irregular shape for Type I granules; vacuoles devoid of material for Type II granules; and mucous vacuoles indistinct or being formed into exceptionally large masses. Similar ultrastructural changes are reported in parotid cells of rats fasted as little as 72 hours (Poort and Kramer, 1969; Wilbom and Schneyer, 1970; Hand, 1972).

In the lumen of the salivary duct degenerating mitochondria and vesicles were seen, while the secretory product was membrane bound. Secretory granules and mucous vacuoles were expelled essentially intact (Fig. 7, Fig. 8, Fig. 9) and not secreted by fusion of vacuolar membrane with plasma membrane as reported by Walker (1970). These observations of *I. obsoleta* support the proposition by Brown (1969) that the secretory product is expelled by volume pressure of product built up in the cell. The secretory product and any degenerating organelles are then transported by cilia of the salivary duct cells to the buccal cavity.

SUMMARY

The three salivary gland cell types of *I. obsoleta* have a similar ultrastructure, but different secretory granules. Type I granule is an electron opaque vacuole, Type II granule is more electron lucent with fusion of the vacuoles and the mucous vacuoles are the most electron lucent with the highest degree of fusion of the vacuoles. Ultrastructure of the cells is compared to previous ultrastructural studies of molluscan salivary glands. Starvation resulted in lightly staining cytoplasm, reduction in glycogen granules and altered secretory granules. These results are similar to ultrastructural changes reported for parotid cells of fasted rats.

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ASPECTS OF MORPHOMETRICS
AND REPRODUCTION OF THE SQUID
OMMASTREPHEP TEROPUS, STEENSTRUP 1885
IN THE WESTERN GULF OF MEXICO

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ABSTRACT

A collection of 401 orange-back squids was obtained during nine easonal cruises between 1975 and 1979. Squids were attracted with ight lights and captured with dip nets, hand-held squid jigs or automatic quid jig machines. *Ommastrephes pteropus* was observed and collected n all seasons, with the largest catches recorded from the western Bay of ampeche, Mexico in June. Largest catches occurred during the new oon. Females were significantly larger than males, (a mean of 21.6 cm antle length vs a mean of 15.4 cm mantle length) but females were gnificantly outnumbered by males in the catch. (36.1 percent vs 63.9 ercent). Sexually mature males and females were collected in winter, ring and summer; spawning therefore may take place year-round in e Gulf of Mexico. Two mature females contained approximately 2,600 and 186,500 mature ova when captured. The gut contents (1) rowed that crustaceans, fishes and squids were preyed upon, and (2) uggested that food habits change with increasing size of squid. The giant erve axons of this species measure 200 to 450µm in diameter.

INTRODUCTION

The orange-back squid, *Ommastrephes pteropus* Steenstrup, 1885, is a large oceanic squid that lives over deep water beyond the edge of the continental shelf throughout the tropical and temperate Atlantic Ocean. In the western Atlantic it is reported northward to Nova Scotia and southward from Bermuda, the Gulf of Mexico and Caribbean Sea (Voss, 1956, 1960, 1971 and 1973). This species occurs from the surface, where it is often observed at night under lights, to a depth of at least 1000 m (Baker, 1957; Voss, 1967 and Roper and Young, 1975). *Ommastrephes pteropus* may be most readily distinguished from a morphologically similar sympatric species that also inhabits the western Atlantic, *Ommastrephes bartrami*, by a large oval bioluminescent light organ located dorsally on the anterior end of the mantle (Lipka, 1975) and by comparative measurements of the beaks (Wolff and Wormuth, 1979). The only reported fisheries for *O. pteropus* take place off the coast of Mauritania (Hamabe, 1975) and in summer at Madeira in the eastern North Atlantic where it is used for bait and human consumption (Clarke, 1966).

The biology and life history of *O. pteropus* are not well known. The location, structure and biochemistry of light organs in this species have been studied extensively (Clarke, 1965; Roper, 1963, Girsch, Herring and McCapra, 1976). The general behavior of *O. pteropus* at night near the surface in the eastern North Atlantic was reported by Baker (1960), Clarke (1966) and Vovk and Nigmatullin (1972). Adam (1952) presented menistic and morphometric data for this species from the west coast of Africa, and recently Zuev and Zaika (1977) estimated the age and growth of this species.

There is pertinent literature on *O. bartrami*. Murata, Ishii and Araya (1976), Murata and Ishii (1977) and Ishii (1977) examined the commercial catch of *O. bartrami* near Japan and described the seasonal distribu-

Table 1. Summary of data for stations at which *O. pteropus* were collected.

RESEARCH VESSEL	DATE	SEASON	NO. OF SAMPLING LOCATIONS	NO. OF SPECIMENS	BOTTOM DEPTH RANGE (m)	SURFACE TEMP. RANGE (°C)	SURFACE SALINITY RANGE (ppt)
GILLIS	Nov. 75	Fall	2	1	1720 - 2100		
GILLIS	Apr. 76	Spring	3	4	1825 - 2100		
GILLIS	Feb. 77	Winter	14	27	212 - 3835	19 - 26	33 - 36
ISELIN	Aug. 77	Summer	14	16	200 - 4000	29 - 30	34 - 36
LEDDY-JONES	Nov. 78	Fall	1	0	237	25.5	35
ONJUKU	June 78	Summer	12	339	860 - 3094	29 - 30	37
LEDDY-JONES	July 78	Summer	3	3	915	29.5 - 30	34
ONJUKU	Aug. 78	Summer	4	0	910 - 1820	29.5 - 30	
ONJUKU	Apr. 79	Spring	13	11	182 - 3349	25.2 - 26.4	

tion and migration, morphometrics, growth, sexual development and spawning season of this species. In the Atlantic, Gaevskaya and Nigmatullin (1976) have described North and South Atlantic populations of *O. bartrami* and examined its primary foods and parasites.

The present study is based upon a collection of 401 specimens of *O. pteropus* from the western Gulf of Mexico collected during nine cruises of four research vessels (Table 1). Primary objectives include examination of the morphometrics, sex ratio, sexual development, size at maturity, fecundity, food habits and giant axon diameter of this species in the western Gulf of Mexico.

MATERIALS AND METHODS

Ommastrephes pteropus was attracted at night to the Mexican vessel ONJUKU with eighteen 2000 watt incandescent lights, and 350 squids were captured with squid jigs fished from four semi-automatic, double-reel squid jig machines. These specimens were usually sexed, the mantle length (ML) measured (mm) and the total body weight (g) taken, but few were preserved for later study. Aboard the three U.S. vessels, *O. pteropus* was attracted with a variety of 500 and 1000 watt incandescent and quartz-iodide lights, and dip nets or various squid jigs fished with rod and reel were used to collect 51 squids. These specimens were dissected for nerve axon measurements, then preserved in 10 per cent formalin and later transferred to 55 per cent isopropanol. These specimens were sexed, weighed to the nearest 0.1 g with a Mettler electronic balance, and their mantle lengths measured to the nearest mm. Contents of the caecum and stomach were examined and classified as empty or containing fish, crustacean or squid remains.

The reproductive condition of 56 specimens was determined by two methods. First, the reproductive system was examined visually and classified as immature (Stage I, no development of gonads), maturing (Stages II and III, enlargement of the testis or ovary and associated glands) or mature (Stage IV, well developed spermatophores or mature ova present). Second, a gonosomatic index (GI) consisting of the ratio of the reproductive system weight (RSW) to the total body weight (TBW) was calculated. The entire reproductive system of 16 males (testis, spermatophoric apparatus, and spermatophores) and 29 females (ovary, two oviducts with ova and two nidamental glands) was dissected and weighed to the nearest 0.01 g.

The fecundity of two mature Stage IV females was estimated using a gravimetric analysis. In *O. pteropus* mature ova are maintained until

spawning in two convoluted membranous oviducts. These oviducts were dissected and weighed to the nearest 0.01 g. Each oviduct was divided into three approximately equal sections and a subsample of between 0.05 and 0.11 g of mature ova was removed from each section. The diameter of ten ova from each subsample was measured and the number of ova in each oviduct was extrapolated from the three subsample counts.

RESULTS

Captures

Ommastrephes pteropus were observed and captured throughout the western Gulf of Mexico (Figure 1). Three specimens of *O. bartrami* (14.4 to 15.0 cm ML) were also collected. Of the 37 U.S. sampling locations, *O. pteropus* was collected from 57 per cent and observed at 78 per cent. Of the 29 Mexican stations, this species was collected from 62 per cent and observed at 83 per cent of the stations. Both Mexican and U.S. stations were primarily located on the periphery of the Gulf of Mexico basin in water depths ranging from 183 to approximately 4000m (Table 1). *Ommastrephes pteropus* was observed and collected in all four seasons (Figure 1), but the lack of uniform replicate samples prevents quantitative comparisons among seasons or locations. The largest catches took place during the June 1978 cruise of ONJUKU in the western Bay of Campeche (Figure 1A). At one station near Cabo Rojo, 128 squids weighing nearly 33 kg were captured in nine hours of squid jigging. In the U.S. cruises the most reliable locations for capturing *O. pteropus* were near Campeche Canyon in the eastern Bay of Campeche and near Vera Cruz in the western Bay of Campeche (Figure 1B).

Morphometrics

A length frequency distribution was obtained from the total catch and separately for males and females (Figure 2). Mean mantle length of the entire sample was 20.7 cm, while that of males was 15.4 cm and that of females was 21.6 cm. A t-test (Table 2) determined that females were significantly larger than males ($.01 < p < .001$). All sexed specimens with mantle lengths greater than 23 cm were females.

Length-weight relationships were calculated separately for males and for females (Figure 3). This relationship for both sexes most closely corresponded to the equation

$$W = aL^b$$

where W = weight, a = the y-intercept, L = mantle length and b = slope

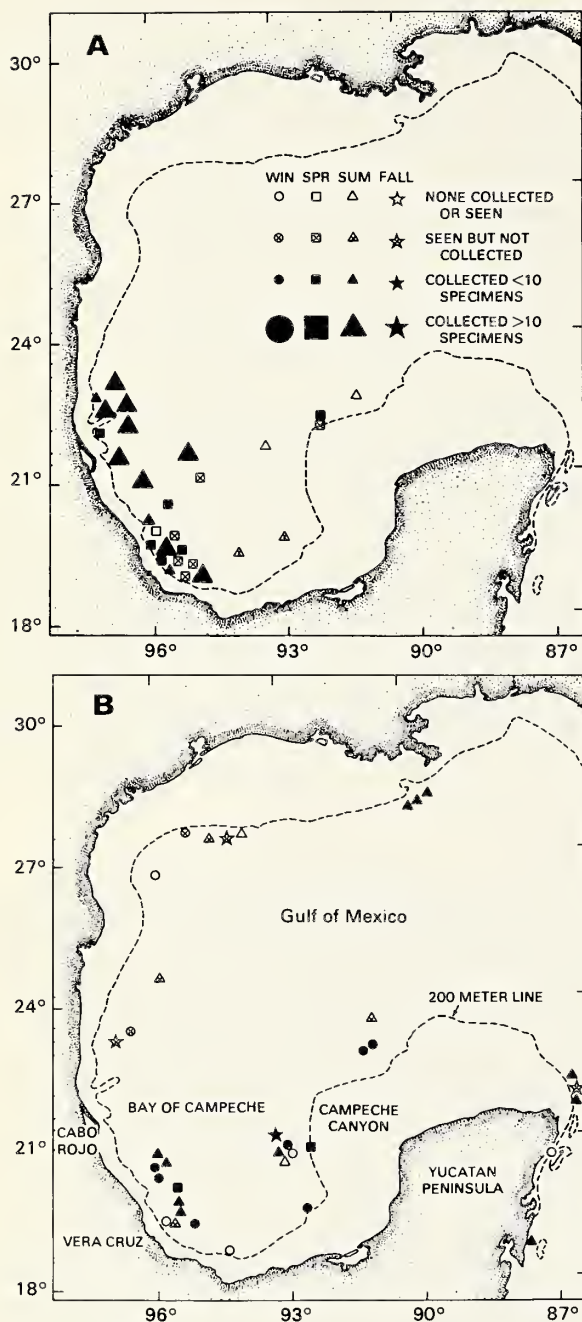


Figure 1. Position of stations occupied by Mexican (A) and U.S. (B) research vessels with a summary of the observations and captures of *O. pteropus* at each location.

of the line. An analysis of covariance of the linear forms of these equations did not detect any difference in slope between the two lines, but it did detect a significant difference in elevation ($p < .001$). Therefore, females are heavier than males at a particular mantle length, but the rate of change in weight as length increases is the same for the two sexes. The length-weight relationship derived for *O. pteropus* collected from the eastern Atlantic by Zuev and Zaika (1977) of $W = 0.0111L^{3.166}$ is very similar to those derived in the present study. Unfortunately, it was not possible with the available material to estimate the life span, age or growth of *O. pteropus*. Based upon seasonal length frequency analyses of the catch of *O. pteropus* (Zuev and Zaika, 1977) and *O. bartrami* (Ishii, 1977), it is likely that these squids live for approximately one year.

Sex Ratio

The sex ratio of 300 *O. pteropus* was 63.9 percent males to 36.1 percent females. It was found to differ significantly ($p < .01$) from 1:1 using a Chi-square goodness-of-fit test. In six of seven ONJUKU stations in which more than ten specimens were collected and sexed, the sex ratio was found also to differ significantly from 1:1 (Table 3). Males outnumbered females in six of these seven stations. Females outnumbered males in one ONJUKU station and in the combined GILLISS-ISELIN catch.

The reason for the difference from an expected 1:1 sex ratio is unclear. We believe that gear selectivity contributed to the observed difference because jig size will select for a particular size (and therefore sex) of individuals. It is likely also that males and females are segregated into discrete schools or shoals. Our own and previous observations of *O. pteropus* near the surface at night (Baker, 1960; Clarke, 1966) have

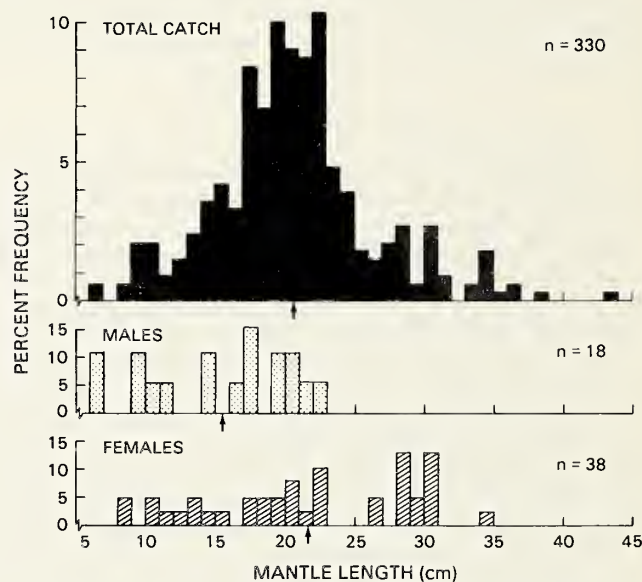


Figure 2. Length frequency analyses of the unsexed and sexed catch of *O. pteropus*. Arrows designate mean size of each group.

Table 2. Comparison of mean mantle length of female and male *O. pteropus* by student's t-test.

FEMALE			MALE			t VALUE	DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE
MEAN ML (cm)	$\bar{S}_x$	n	MEAN ML (cm)	$\bar{S}_x$	n			
21.6	1.20	38	15.4	1.19	18	3.21	54	.001 < p < .01

indicated that (1) similar size animals school together and that (2) the number of squids constituting a school generally decreases as the size of individuals increase. The largest-sized individuals are often solitary and most likely are females. Differences from the expected 1:1 sex ratio may result from spatial and seasonal differences in the distribution of these schools, but more quantitative study is needed to verify these observations.

Sexual Maturity

Mature Stage IV males and females were collected in winter, spring and summer (Table 4); too few specimens were taken to establish if mature squids also occur during fall. Mating activity, indicated by the presence of spermatophores (always less than ten) attached to the buccal mass, also takes place throughout the year, with the possible exception of

the fall. All Stage IV females and two Stage III females collected in winter had mated shortly prior to capture. From these observations it seems likely that some spawning occurs year-round in the Gulf of Mexico.

Both the numerical gonosomatic index and the visual examinations of the reproductive system are necessary to properly evaluate the reproductive condition of mature males and females. The loss of spermatophores in mating or the possible occurrence of multiple spawnings in females would result in a low numerical GI value that underestimates the degree of sexual development. For example, mature Stage IV males contained between 25 to 270 spermatophores.

A regression analysis between the reproductive system weight (RSW) and mantle length (ML) of males and females (Figure 4) shows that the RSW is poorly correlated to ML (correlation coefficient r^2 value of .84 for males and .78 for females). For example, the size at maturity differed considerably among males and among females. The smallest mature Stage IV male was 14.2 cm ML while the largest immature Stage III male was 17.2 cm ML. In females, one specimen was mature at 21.0 cm, while the largest specimen in this collection (34.5 cm ML) was in an immature Stage II condition.

Fecundity

Mature ova removed from the oviducts are amber to rose in color and are irregular in shape when preserved. Mean diameter of 60 ova measured from three sections of the left oviduct of the two Stage IV females was 0.76 mm (range 0.64 to 0.88 mm, standard error 0.006 mm).

Fecundity was conservatively defined in this study as the number of ova in the oviducts at the time of capture. Mean fecundity estimates of the two mature females were 52,618 and 186,461 (Table 5). Ripening oocytes of various diameters also were present in the ovary of both

Table 3. Comparison of sex ratio (Chi-square goodness-of-fit tests) of *O. pteropus* collected from (1) seven ONJUKU stations conducted in summer (June, 1978), (2) the combined GILLISS and ISELIN catch and (3) the combined ONJUKU, GILLISS and ISELIN catch.

RESEARCH VESSEL	NO. MALES	NO. FEMALES	CHI-SQUARE VALUE	LEVEL OF SIGNIFICANCE
ONJUKU	25	5	13.33	ps.01
ONJUKU	14	7	2.33	NS
ONJUKU	17	49	15.52	ps.01
ONJUKU	67	8	46.40	ps.01
ONJUKU	11	0	11.00	ps.01
ONJUKU	18	1	15.21	ps.01
ONJUKU	22	11	11.64	ps.01
GILLISS & ISELIN	18	38	7.14	ps.01
ONJUKU, GILLISS & ISELIN	198	112	23.86	ps.01

Table 4. Summary of characteristics of maturation stages and seasonal catch of *O. pteropus* by sex.

MATURITY STAGE	MORPHOLOGICAL CHARACTER	RANGE OF GONOSOMATIC INDEX: RSW/TBW	RANGE OF RSW (g)	RANGE OF ML (cm)	CATCH BY SEASON			
		(%)			WINTER	SPRING	SUMMER	FALL
<u>MALES</u>								
I	Testis and hectocotylus not developed.	0.1 - 1.5	.01 - 0.43	6.8 - 9.6			3	
II	Testis enlarged, hectocotylus partially developed.	~1.6 - ~3.0	0.93	11.8			1	
III	Hectocotylus complete, few or no spermatophores present.	3.1 - 4.5	2.43 - 5.39	10.9 - 17.2		2	1	
IV	Many fully developed spermatophores present.	2.5 - 7.0	5.79 - 15.90	14.2 - 22.4	6	*	3	
TOTAL MALE SPECIMENS					6	2	8	0
<u>FEMALES</u>								
I	Ovary and nidamental glands not developed.	0.1 - 0.5	0.01 - 1.13	8.1 - 17.4	4	1	1	
II	Ovary and nidamental glands enlarged.	0.5 - 1.0	0.31 - 14.97	10.2 - 34.5	8	1	4	1
III	Ovary granular with developing oocytes.	1.0 - ~10.0	8.86 - 28.21	20.0 - 28.8	5		1	
IV	Many mature ova in oviducts.	~10.0 - 16.0	41.46 - 156.29	21.0 - 29.0	1	*	1	
TOTAL FEMALE SPECIMENS					18	2	7	1

* One Stage IV male and nine Stage IV females were also collected on the April, 1979 ONJUKU cruise, but the reproductive system weights were not obtained.

~ approximate value

specimens (Figure 5); therefore, additional mature females are needed to correctly quantify the total number of ova produced by a single female. In comparison, the fecundity reported for other species in the family Ommastrephidae are higher. Durward, Amaratunga and O'Dor (1979) estimated an average fecundity of 400,000 + 40,000 ova for *Illex illecebrosus* and Clarke (1966) reported 360,000 ova from one *Ommastrephes caroli*.

Food Habits

The caecum and stomach contents of 35 female and 16 male *O. pteropus* were examined. Nineteen guts were found to be empty, five contained crustacean carapace remains, 20 included fish scales and bones, and 19 held squid flesh, beaks or eye lenses. No specific identifications were made due to the macerated or partially digested condition of gut contents. A comparison of the gut contents with mantle length suggests that food habits change with size. Smaller squids (mean ML 11.5 cm; range 6.8 to 20.6 cm) consumed crustaceans primarily. Larger squids (mean ML 19.5 cm; range 10.2 to 31.0 cm) contained fish remains, while the largest squids (mean ML 22.6 cm; range 10.1 - 31.0 cm) consumed other squids. Both males and females showed similar size differences in food habits.

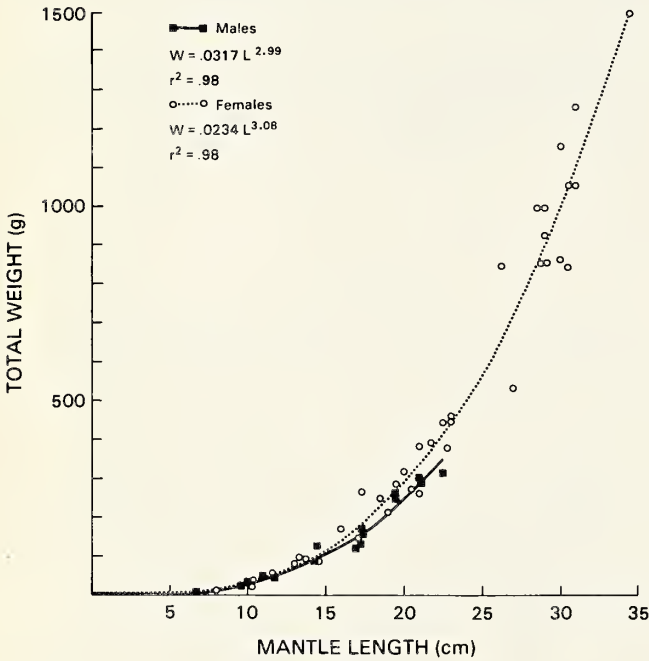


Figure 3. Length-weight relationship of male and female *O. pteropus*.

Catch and Moon Phase

The catch of *O. pteropus* from 64 locations was segregated into four groups based upon the phase of the moon (Table 6). No statistical comparisons were carried out among catches made during various moon phases because large differences occurred in station duration (15 minutes to 10.5 hours per station). No obvious differences were observed in the percentage of stations in which at least one specimen was collected (39 to 62 per cent) among the four moon phases. In terms of numbers caught, 80.3 per cent of the 401 squids captured were collected during the new moon when 56 per cent of the stations took place. In contrast, only 5.2 per cent of the total catch (21 individuals) were captured during the first quarter and full moon periods. These observations support previous reports by Baker (1960) that catches of *O. pteropus* are affected by the phase of the moon.

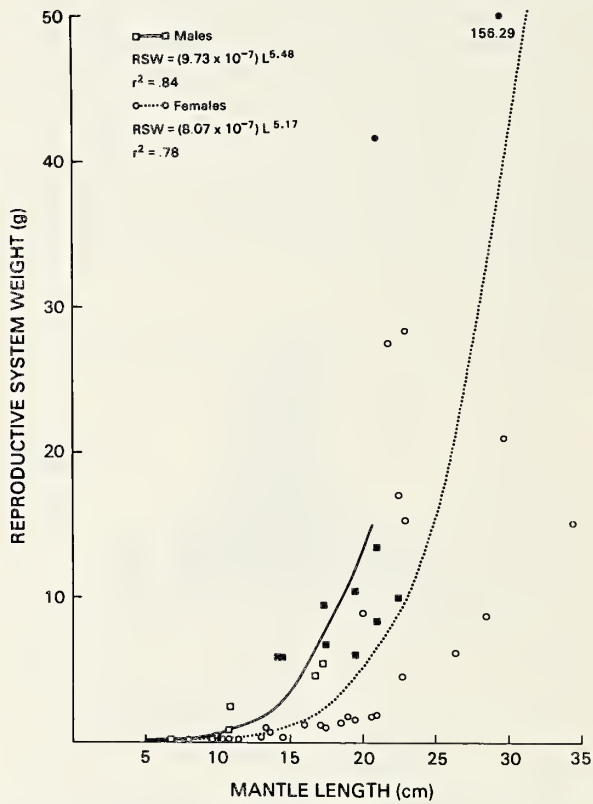


Figure 4. Relationship of the weight of the male and female reproductive system and mantle length.

Table 5. Fecundity of two <i>O. pteropus</i> females with upper and lower 95 per cent confidence limits (CL).											
ML (cm)	RSW (g)	GI (%)	RIGHT OVIDUCT			LEFT OVIDUCT			FECUNDITY ESTIMATE		
			WEIGHT (g)	MEAN NO. OVA	Sx	WEIGHT (g)	MEAN NO. OVA	Sx	NO. OVA	UPPER 95% CL	LOWER 95% CL
21.0	41.46	10.9	4.46	24,312	811	4.52	28,306	696	52,618	59,103	46,133
29.0	156.29	15.7	18.10	96,815	1568	21.10	89,646	1012	186,461	197,563	175,358

RSW - Reproductive System Weight
GI - Gonosomatic Index

Nerve Axon Diameter

The stellate ganglia and associated stellar nerves were dissected from three females (285, 264 and 225 mm ML), fixed in osmium tetroxide, embedded in resin, sectioned for light microscopy and measured with an optical micrometer. The first stellar nerve was found to be a large nerve bundle that contained three giant fibers. In the largest squid specimen the diameters of these three axons were 445, 261 and 387 μ . Stellar nerve bundles radiating from the mid-portion of the stellate ganglion each contained a single axon ranging from 200 to 400 μ in diameter. These measurements indicate that the axon diameter of *O. pteropus* is similar to that of adult *Loligo pealei* (Arnold, et al., 1974), and that they are of suitable diameter for nerve axon experiments.

DISCUSSION

Ommastrephes pteropus is the most commonly observed and, from an ecological view, perhaps the most important large cephalopod in the near-surface waters at night in the western Gulf of Mexico. Because it is so large and numerous it has potential both as a fisheries resource and as research material.

Further systematic study is needed to properly determine if *O. pteropus* can be fished commercially with squid jigs in the western Gulf. Additional quantitative information must be obtained on seasonal distribution and abundance using catch per unit effort statistics collected under standardized lighting and squid jigging conditions. Although several aspects of the life history of this species were examined in the present study, these results should be considered as preliminary due to the small sample size and the lack of standardized capture techniques.

Our initial observations of *O. pteropus* in captivity have shown that this species is very difficult to maintain alive. We have kept live animals aboard ship in circular, 2 m diameter, 1500 l fiberglass tanks for up to three days. During that time they nearly continuously chafed against the sides or bottom of the tank, causing extensive fin and skin abrasion. They also were highly cannibalistic; the largest squid ate its smaller conspecifics even when several live fishes were available in the tank. Therefore, experimentation using live *O. pteropus* would be carried out best at present aboard ship soon after capture.

ACKNOWLEDGEMENTS

We thank R.T. Hanlon, and S. v. Boletzky, for critically reviewing

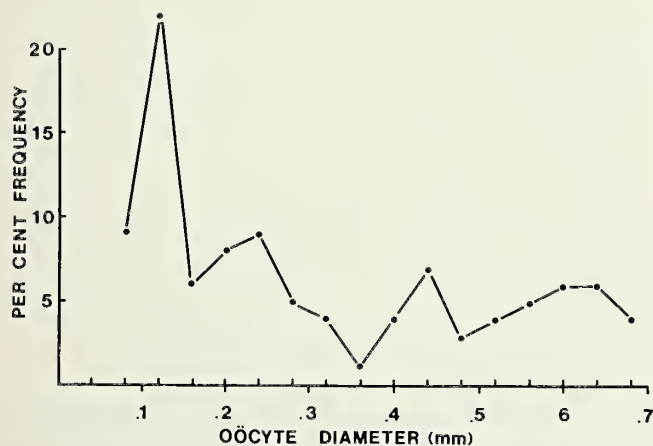


Figure 5. Size frequency relationship of 100 oocytes removed from the ovary of a mature Stage IV female *O. pteropus* (21.0 cm ML) with a gonosomatic index of 10.9 percent.

Table 6. Catches of *O. pteropus* during four moon phases.

	NEW	MOON PHASE		
		FIRST QUARTER	FULL	THIRD QUARTER
NO. STATIONS	37	13	11	5
NO. SUCCESSFUL* STATIONS	23	5	6	3
PER CENT SUCCESS	62.2	38.5	54.5	60.0
NO. SQUIDS CAUGHT	322	11	10	58
PER CENT TOTAL CATCH	80.3	2.7	2.5	14.5

* Success defined as the capture of at least one squid during the station.

the manuscript and providing helpful comments. The authors also wish to thank W.H. Hulet for his assistance with the nerve axon preparations and measurements. We gratefully acknowledge Dr. J. Carranza Fraser for supporting part of this work and for providing travel funds. Shiptime support on the R/V JAMES M. GILLISS and R/V COLUMBUS ISELIN was obtained through National Science Foundation Grant NSF-BMS-7508675. This work was supported in part by Grant No. RR 01024 04 from the Division of Research Resources, National Institutes of Health, and the Marine Medicine General Budget account No. 7-11500-765111 of the Marine Biomedical Institute, University of Texas Medical Branch.

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THE MOLLUSCAN FAUNA OF THE DUCK RIVER BETWEEN NORMANDY AND COLUMBIA DAMS IN CENTRAL TENNESSEE

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ABSTRACT

Thirty-one species of freshwater mussels and eight species of freshwater snails were found living in the Duck River between Normandy Dam and the city of Columbia. Previous surveys indicate a drastic decline in the mussel fauna. Recent surveys from 1976 and 1978 confirm that indication.

The Duck River, located in central Tennessee, flows from the eastern Highland Rim Plateau in Coffee County westward through Bedford, Marshall, Maury, Hickman, and Humphreys Counties where it joins the Tennessee River at Kentucky Reservoir (Tennessee River Mile (TRM) 110.7). The Duck River is 290 miles long, 270 miles are free flowing at the present time.

The Duck River is one of several major tributary streams which form the headwaters of the upper Tennessee River system. These river systems contain freshwater mussel species that are endemic to the southern Appalachian Mountains and the Cumberland Plateau region. Ortmann

(1924) referred to these species as "Cumberlandian." Only the upper half of the Duck River contains Cumberlandian species; the lower portion is inhabited by members of the Ohioan or Interior faunal group and those of undetermined origin (Ortmann, 1924; van der Schalie, 1973). Over the last 50 years, a rich molluscan fauna has been reported from the Duck River. Previous surveys of the Duck River were conducted by Ortmann (1924); van der Schalie (1939, 1941); Isom and Yokley (1968). The results of these surveys indicate that at least 63 species, subspecies, and forms of freshwater mussels (Ortmann, 1924) and 9 species of river snails (Goodrich, 1940; 1941) once occurred in the Duck River.

With the passage of the Endangered Species Act by Congress in 1973, the presence of endangered freshwater mussels in the Duck River has become an important factor affecting the continuation of the Columbia Dam Project. The construction of dams, stream channelization, pollution and silt from strip mines, and coal washing facilities has restricted the Cumberlandian fauna to a few isolated populations in rivers such as the Powell, Clinch, Duck, and the South, Middle, and North Fork Holston (Ahlstedt and Brown, 1980). Isom and Yokley's (1968) survey of the Elk River indicates a 55 percent reduction of Cumberlandian forms reported by Ortmann.

The upper Duck River Regional Planning Commission was formed in 1964 to prepare plans for development of the water resources in the Duck River. The final plans called for the Tennessee Valley Authority

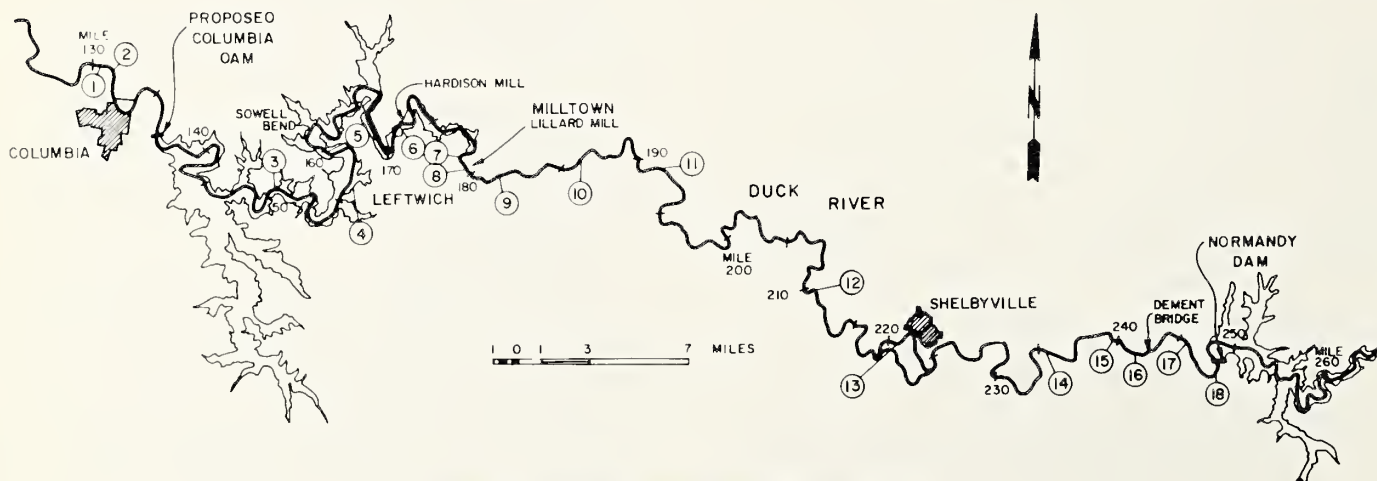


Figure 1. Duck River Collecting Sites, 1976 and 1978

(TVA) to construct two dams (at Normandy, DRM 248.6, and at Columbia, DRM 136.9) which would provide flood control, water supply, water quality control, recreation, and fish and wildlife development. Normandy Dam was the first of these two dams to be completed with closure in 1976. Columbia Dam is currently under construction with closure scheduled for 1985.

This report combines the results of two mollusk surveys completed by the author on the Duck River to assess the status of Federally listed and proposed species which may be affected by completion of Columbia Dam.

During 1976 and 1978, collections were made at 18 sites on the central Duck River (Table 1) using wading, snorkeling, and scuba diving sampling techniques. These collections documented the continued existence of 31 species of freshwater mussels and 8 species of river snails in this reach of the river (Table 2, Figure 1). The most productive site sampled for mussels occurred at DRM 179.0 (site 8), and DRM 156.5 and 187.0 (sites 4 and 10) for river snails.

The freshwater mussel fauna of the Duck River was relatively diverse as recently as 1965 with 47 species reported (Isom and Yokley, 1968). A mollusk survey conducted in 1972 (TVA and consultants, unpublished) yielded only 30 species of freshwater mussels and 7 species of snails. This decline was noted by van der Schalie (1973) who reported that "where once shoals were literally paved with mussels not even fragments of dead shells are now in evidence!"

During the 1976 and 1978 surveys, sites above Lillard Mill (DRM 179, site 8) were practically devoid of any living mussels; living individuals of only four species were found (Table 2). At Lillard Mill, a good mussel fauna still exists with 26 species of mussels present. Numerous dead shells were found at collecting sites downstream from Lillard Mill and heavy accumulations of silt were present at sites 3, 4, 5, and 6 adjacent to the Columbia Dam construction area.

Seven mussel species listed as endangered by the U.S. Fish and Wildlife Service had previously been reported from the Duck River. Six of these species (*Quadrula intermedia*, *Dysnomia florentina florentina*, *Dysnomia turgidula*, *Dysnomia walkeri*, *Pletobasus cooperianus*, and *Carunculina cylindrella*) were not found during these surveys; however, living specimens of *Conradilla caelata*, the other endangered species, were found at four sites (Table 2). Although *Quadrula intermedia* was not found during the surveys discussed here, this species was found alive at three sites on this river in May 1979 during an intensive float survey from Normandy Dam to Columbia.

In 1976, 18 living specimens of *Conradilla caelata* were found at DRM 131.0 (site 2), but only one in 1978. All of these individuals are believed to be members of a population of 49 specimens that were transplanted into this site in 1975 by Dr. Paul Yokley. * Similar transplants made below the mill dam at Shelbyville, DRM 221.2 (site 13), were never located.

The river snails in the Duck River were found to be common except below Normandy Dam, DRM 245 to 248.6 (sites 17 and 18) where only one species of snail (*Goniobasis laqueata*) was found. Whatever caused the rapid decline in the mussel fauna apparently has had little impact on the river snails in the Duck River.

Six species of river snails (proposed for Federal listing as endangered species by the Fish and Wildlife Service) have been reported from the Duck River. To date, these species have been withdrawn from the Federal endangered species list. Two of these species (*Lithasia* (= *Io*))

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Table 1
Collecting Sites, Duck River
1976 and 1978

Sites	Location	River Mile
1	One mile below the Old Mill Dam at Columbia, Maury County, Tennessee.	131.0
2	Below Old Mill Dam at Columbia, Maury County, Tennessee.	132.0
3	Interstate 65 bridge crossing, Maury County, Tennessee.	151.5
4	Below Sowell Mill Pike bridge crossing at Leftwich, Maury County, Tennessee.	156.5
5	Sowell Bend, Maury County, Tennessee.	160.0
6	Below Hardison Mill Dam, Maury and Marshall Counties, Tennessee.	172.5
7	Below mouth of Creek Island, Marshall County, Tennessee.	178.2
8	Below Lillard Mill Dam at Milltown, Marshall County, Tennessee.	179.0
9	Powell Bluff, Marshall County, Tennessee.	183.0
10	Below Wilhoite Mill Dam near Henry Horton State Park, Marshall County, Tennessee.	187.0
11	Shearin Ford, Marshall and Bedford Counties, Tennessee.	192.5
12	Temple Ford, Bedford County, Tennessee.	212.2
13	Below Shelbyville Dam, Bedford County, Tennessee.	221.2
14	Tennessee Highway 41 alternate bridge crossing at Mullins Mill, Bedford County, Tennessee.	235.7
15	Below Three Forks bridge crossing above Garrison Fork Creek, Bedford County, Tennessee.	239.8
16	Dement bridge crossing, Bedford County, Tennessee.	243.1
17	Below Courtners Mill Dam, Bedford County, Tennessee.	245.0
18	Below Normandy Dam, Bedford County, Tennessee.	248.6

geniculata pinguis and *Lithasia* (= *Io*) *salebrosa*) were not found during these surveys; however, living specimens of *Anculosa* (= *Leptoxis*) *praerosa*, *Lithasia* (= *Io*) *armigera duttoniana*, and *Lithasia* (= *Io*) *geniculata geniculata* were found to occur throughout the study reach (Table 2). Another species of river snail identified as *Lithasia* (= *Io*) *armigera jayana* was also found throughout the study reach. Davis (1974) has previously reported this species from the Duck River where he found typical specimens of *jayana* in the lower Duck River (DRM 20-70) and specimens "with weakly developed *jayana* traits" farther upstream toward Manchester (DRM 260).

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Table 2
Mollusk Distribution - Duck River
1976 and 1978

Species	Collecting Sites																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mussels:																		
<i>Actinonaias carinata</i> (Barnes 1823)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
+ <i>Actinonaias pectorosa</i> (Conrad 1834)	-	-	-	X	-	-	X	-	-	-	-	X	X	-	-	-	-	-
<i>Amblema costata</i> (Barnes 1823)	X	X	-	X	X	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Anodonta grandis</i> Say 1829	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+ <i>Carunculina lividus</i> (Rafinesque 1831)	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
+* <i>Conradilla caelata</i> (Conrad 1834)	-	X**	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
<i>Cyclonaias tuberculata</i> (Rafinesque 1820)	X	X	X	X	X	-	-	X	-	X	X	-	-	-	-	-	-	-
+ <i>Dysnomia brevidens</i> (Lea 1831)	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
+ <i>Dysnomia capsaeformis</i> (Lea 1834)	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Elliptio dilatatus</i> (Rafinesque 1820)	-	-	-	X	X	X	X	X	-	X	-	-	-	-	-	-	-	-
+ <i>Fusconaia barnesiana</i> (Lea 1838)	-	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Lampsilis fasciola</i> (Rafinesque 1820)	-	X	-	X	X	-	X	X	-	-	-	-	-	-	-	-	-	-
<i>Lampsilis ovata</i> (Say 1817)	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Lasmigona costata</i> (Rafinesque 1820)	X	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-
<i>Leptodea fragilis</i> (Rafinesque 1820)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
+ <i>Lexingtonia dolabelloides</i> (Lea 1840)	-	-	X	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-
+ <i>Medionidus conradicus</i> (Lea 1834)	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-
<i>Megaloniais gigantea</i> (Barnes 1823)	X	X	-	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-
+ <i>Micromya taeniata</i> (Conrad 1834)	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-
+ <i>Micromya vanuxemensis</i> (Lea 1838)	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Oblivaria reflexa</i> (Rafinesque 1820)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Obovaria subrotunda</i> (Rafinesque 1820)	-	-	-	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-
<i>Pleurobema cordatum</i> (Rafinesque 1820)	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-
+ <i>Pleurobema oviforme</i> (Conrad 1834)	-	-	X	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-
<i>Proptera alata</i> (Say 1817)	X	X	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-
<i>Ptychobranchius fasciolaris</i> (Rafinesque 1820)	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
+ <i>Quadrula cylindrica</i> (Say 1817)	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Quadrula pustulosa</i> (Lea 1831)	X	X	-	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-
<i>Quadrula quadrula</i> (Rafinesque 1820)	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
<i>Tritogonia verrucosa</i> (Rafinesque 1820)	X	X	-	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-
<i>Truncilla truncata</i> Rafinesque 1820	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
Snails: Collected only in 1978																		
<i>Anculosa</i> (=Leptoxis) <i>praerosa</i> (Say 1821)	X	X	X	X	X	X	X	X	N	X	X	X	X	X	X	X	-	-
<i>Goniobasis edgariana</i> (Lea 1841)	-	-	-	X	-	X	-	X	O	X	-	-	-	-	-	-	-	-
<i>Goniobasis laqueata</i> (Say 1829)	X	X	X	X	-	X	-	X	-	X	X	X	X	-	X	X	X	-
<i>Lithasia</i> (=Io) <i>armigera duttoniana</i> (Lea 1841)	X	X	X	X	X	-	X	X	S	X	X	-	X	X	X	X	-	-
<i>Lithasia</i> (=Io) <i>armigera jayana</i> (Lea 1841)	X	-	-	X	X	X	-	-	A	X	-	-	X	X	X	X	-	-
<i>Lithasia</i> (=Io) <i>geniculata fuliginosa</i> (Lea 1841)	X	X	X	X	X	X	X	X	M	X	X	X	X	X	X	X	-	-
<i>Lithasia</i> (=Io) <i>geniculata geniculata</i> (Haldeman 1840)	-	X	X	X	X	X	-	-	P	X	X	X	X	X	X	X	-	-
<i>Pleurocera canaliculatum</i> (Say 1821)	X	X	X	X	X	X	X	X	L	X	X	X	X	-	-	X	-	-
									E									

+Cumberlandian Species

*Endangered

**These specimens may be transplants made by Dr. Paul Yokley in 1975.

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THE TENNESSEE VALLEY AUTHORITY CUMBERLANDIAN MOLLUSK CONSERVATION PROGRAM

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During the mid-1960's the Tennessee Valley Authority (TVA) was urged by local citizens to study the feasibility of building dams on the Duck River in Central Tennessee. The final TVA proposal that resulted from this study called for the construction of two reservoirs, one in the headwaters at Normandy (River Mile 248) and the other midway between there and the mouth at Columbia (River Mile 137). Normandy Reservoir was started in 1972 and finished in 1976 amid growing concern about the effect of this impoundment on resident endangered

freshwater mussels. Construction on Columbia Reservoir began in 1973 but was essentially halted in 1977.

In 1977 the U.S. Fish and Wildlife Service (FWS) issued a Biological Opinion stating that completion of Columbia Reservoir as originally proposed would be likely to jeopardize the continued existence of two species of freshwater mussels: the birdwing pearly mussel, *Conradilla caelata* (Conrad, 1834) (= *Lemiox rimosus* Rafinesque, 1831), and the Cumberland monkeyface pearly mussel, *Quadrula intermedia* (Lea, 1858). In a 1979 report to the Office of Management and Budget, TVA examined and rejected two alternatives to completing the full pool reservoir but, in their description of the full pool project, presented a brief description of a conservation program for the endangered species and other members of the Cumberlandian mussel fauna. Later in 1979 the FWS issued a Biological Opinion stating that the conservation program

was generally acceptable and that the reservoir could be filled if the program proved to be successful.

The general goal of the Cumberlandian Mollusk Conservation Program (CMCP) is to improve conditions for the survival of endangered and other stream dwelling mollusks that exist only in the headwaters of the Tennessee and Cumberland river systems. The general approach of the program is to obtain new data to substantiate or expand published information and then to use this data base to characterize species and faunal requirements and to evaluate mussel habitat in selected river reaches in the Tennessee River basin.

In its simplest organization the CMCP involves a number of activities separated into two consecutive phases. The first or research phase of the program consists of eight activity leaders assigned the responsibility for development and implementation of nine interrelated activities designed to answer questions about the Cumberlandian mussel fauna and present or potential habitats. Specifically these activities include float surveys of several rivers to update distribution records; field and laboratory studies intended to identify fish hosts for several mussel species; laboratory studies designed to perfect an artificial culture medium for mussel glochidia; and several concurrent studies to describe the physical, chemical, and biological components of 15 actual or potential Cumberlandian mussel habitats scattered throughout the Tennessee River basin. The final activity in this phase of the program will consist of analyzing all of the accumulated data to produce characterizations of the habitat of certain Cumberlandian species and to select transplant sites for mussel specimens now living in the impoundment area of Columbia Reservoir.

The second or conservation phase of the program is designed to apply the foundation of information produced in the research phase. An important activity in this phase will be the actual moving and monitoring of mussel transplants. Other activities, all directed toward maintaining or improving habitat conditions in areas where Cumberlandian species occur naturally, will include various approaches to reducing the amounts

of silt and other materials that are carried into streams, stabilizing and safeguarding gravel beds, and developing and implementing procedures to minimize impacts of present and future human uses of selected watercourses. Additional activities also may be indicated based on the analyses or observations made during the research phase of the program.

Implementation of this program began with a few mollusk and fish surveys that were conducted in 1979. By July 1980 all of the research activities had started field or laboratory work. Completion of the research phase is scheduled for fall 1982, by which time the analysis of data and the selection of transplant sites will have occurred. Conservation phase activities are scheduled to begin after the research analysis has been completed. Transplantation of Duck River mussels is presently scheduled to occur in late fall 1982 and anticipated stream restoration work is proposed to begin in 1983. Monitoring of the transplants and completion of restoration activities may continue for a number of years.

Although this wide-ranging program was proposed and, largely, will be carried out by TVA, representatives of several Federal agencies and three affected states are involved in monitoring its progress and in judging whether it has accomplished its goal. These governmental agencies are represented on a coordination committee which has been charged by the FWS with establishing biological criteria for this program and then evaluating the results of the various activities. If TVA can meet the biological criteria established by the interagency committee, more than likely the FWS will remove the endangered species obstacles to the completion of Columbia Reservoir.

At this point, this program represents an effort of Federal and State agencies to try to resolve an endangered species problem through cooperation instead of confrontation. The next several years will demonstrate how well this effort succeeds. In the interim malacology will gain significant quantities of information about the life history and ecology of the Cumberlandian mollusk fauna.

COMPARISON OF MOLLUSKS RETRIEVED BY CROWFOOT
DREDGE AND PONAR GRAB SAMPLER FROM THE WHITE RIVER
AT ST. CHARLES, ARKANSAS
WITH COMMENT ON POPULATION STRUCTURE OF
CORBICULA FLUMINEA
(*BIVALVIA: SPHAERIACEA*)
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Indigenous molluscan inhabitants of benthic communities in U.S. rivers exhibit a wide size range. The largest animals are the mussels (Unionidae) which may commonly attain a length of more than 12 cm. The smallest animals include gastropods, fingernail clams, and various juvenile molusks, all within a size range of one to 30 mm. When benthic communities of large rivers are studied, however, collecting gear is not selected with the objective of obtaining samples of all animals, both large and small.

Investigators have compared the composition of benthic samples obtained with various kinds of gear (Baker, et al. 1977 and others). A number of workers have analyzed efficacy of collecting gear in such freshwater habitat as shallow streams, deep rivers, lakes, and reservoirs (Wefring and Teed, 1980; Rabeni and Gibbs, 1978; Paterson and Fernando, 1971; and others). Benthic sampling gear effectiveness has been studied in marine habitat from shallow coastal waters and bays to deep sea. Gear effectiveness in substrates such as soft mud bottoms, hard bottoms and artificial substrates has been evaluated. One study (Radford and Hartland-Rowe, 1971) was a comparison of surface and subsurface

sampling techniques. In the literature reviewed, however, no record was found of a study which deliberately set out to sample all animals, regardless of size, on a river bottom.

In November, 1979, plans for a large bridge and approaches to span the White River at St. Charles, (Arkansas County) Arkansas, required a site study to determine presence or absence of the mussel, *Proptera* (= *Potamilus*) *capax*, now listed as an endangered species in the Federal Register. Collections of *Proptera capax* near the proposed bridge site housed in several museums include specimens from: (1) Devalls Bluff, Arkansas, in 1966 (U.A.M.); (2) lower White River in the migratory waterfowl refuge, date unknown, (U.S.M.N.H.); and (3) one mile north of Devalls Bluff, in 1939 (U.M.M.Z.). The White River in Arkansas has been the locale of one of the richer unionid mussel faunas in the world, including at least 58 species (Gordon, et al., 1979). However, no previous data on the benthos of the proposed bridge site at St. Charles existed and seasonal sampling for this study was precluded by time constraints.

Table 1. Location of the four ponar grab sampling transects and number of collection sites and samples from each transect of the White River at St. Charles, Arkansas, November 21 and 26, 1979.

Transect Number	Location of transect in relation to centerline of proposed bridge	No. of collection sites	No. of samples
1	75 feet downstream from centerline	10	30
2	25 feet downstream from centerline	10	30
3	25 feet upstream from centerline	11	33
4	75 feet upstream from centerline	10	30

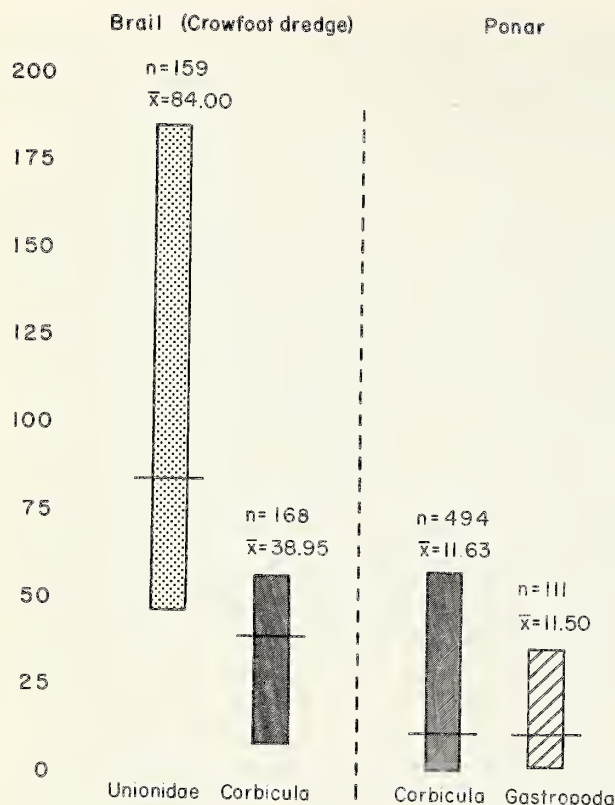


Figure 1. Comparative size dispersal and size range of Mollusca sampled by crowfoot dredge and ponar grab. X represents mean length in mm. Note: occurrence of gastropods in crowfoot dredge samples (indicated in Table 2) was accidental and insignificant and thus is not shown here.

Consequently, a one-time, intensive, overlapping sampling process was undertaken which not only supplied the evidence immediately required concerning *P. capax*, but which also produced substantial baseline data on extant White River biota.

In this paper we present evidence to show: (1) that overlapping collection methods used in this study (crowfoot dredge and ponar grab) allow community structure of benthic mollusk populations to be fully characterized; (2) that the White River bottom study site is inhabited by an essentially molluscan fauna, until recently comprised of indigenous gastropods and mussels, but now conspicuously including the introduced Asian clam, *Corbicula fluminea*; (3) that the successful colonization of the site by *C. fluminea* is associated with disturbance of the substrate and with a diminution of the indigenous fauna; and (4) that *C. fluminea* presently comprises a substantial portion of the small animals (retrieved by ponar grab) and of large animals (retrieved by crowfoot dredge). We note that the size range of local populations of *C. fluminea* now greatly exceeds that of autochthonous mollusks, a feature which is traceable to developmental, behavioral, reproductive and neurobiological peculiarities of the introduced species. We suggest it may be that *C. fluminea* owes a portion of its "success" to this peculiar population characteristic.

MATERIALS AND METHODS

Crowfoot dredge samples were taken in three complete transects of the river bottom at the bridge site on November 21 and 26, 1979. A

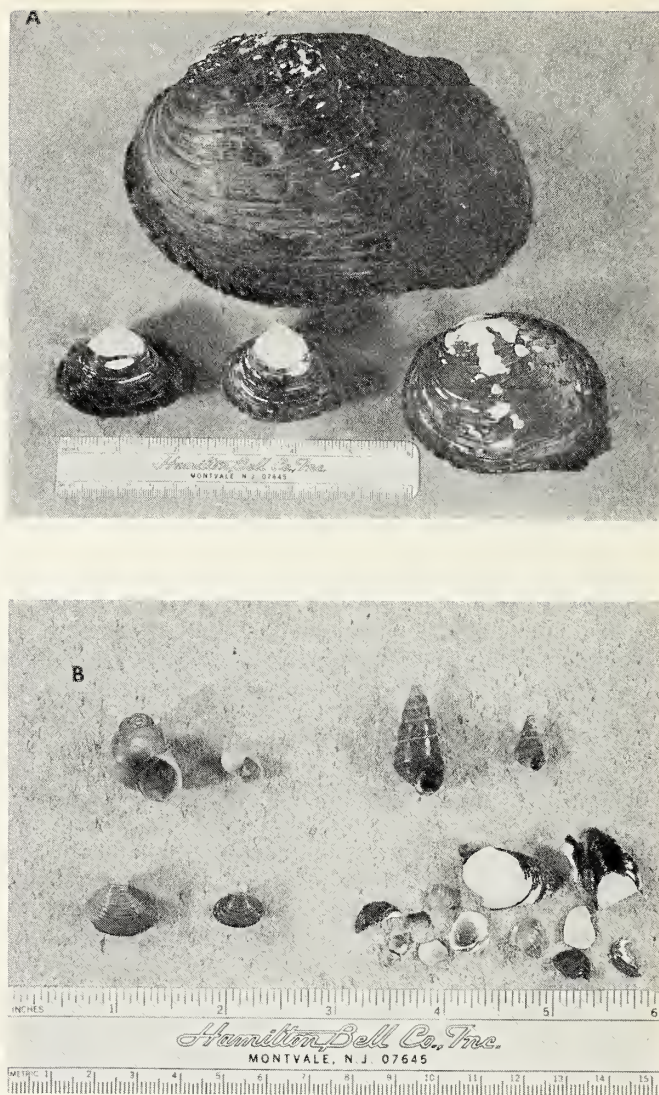


Figure 2. Photographs showing typical molluscan assemblage in samples retrieved from the White River at St. Charles, Arkansas, by means of crowfoot dredge (A) and by means of ponar grab (B).

fourth complete transect series by crowfoot dredge was taken November 26, 1979 at a point 5600 feet downstream from the bridge site. All the mollusks retrieved were relaxed in Nembutal and subsequently fixed in Bouin's fluid or formalin before being saved in ethanol.

Ponar grab samples were taken in four complete river transects at the bridge site using a ponar grab with a 9.5 cm² "bite", (Table 2). In each of the transects the first sampling site was within 50 feet of the southwest bank and subsequent sampling sites were located 50 feet apart, the last sampling site of each transect occurring within 50 feet of the northeast bank. Average river depth at the first sampling site in each series was 8 feet, at mid-river sampling sites 15 feet, and at last sampling site, 15 feet. All grab samples were taken in replicates of three. Replicated samples were combined, sieved through a 30-mesh sieve (openings of 520 µm), and preserved in ethanol.

Animals in the crowfoot dredge samples were identified. Length, width, height and number of annual growth lines were tabulated for each animal. Dimorphic species were sexed. All of each of the ponar grab samples was examined using a Luxo-10X Magnifier Lamp and tech-

TABLE 2
COMPOSITION OF CROWFOOT DREDGE SAMPLES, WHITE RIVER, ARKANSAS 1979-1980

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	Total Specimens
Bivalvia: Unionidae													
<i>Fusconaia ebena</i> (Lea, 1831)	7	1	6	2	6	4	6	4	2	-	-	-	38
<i>Megalonaias gigantea</i> (Barnes, 1823)	1	-	-	-	-	-	-	-	1	1	-	1	4
<i>Amblema plicata</i> (Say, 1817)	-	-	-	-	-	-	-	-	-	-	-	1	1
<i>Quadrula pustulosa</i> (Lea, 1831)	6	2	7	6	4	1	6	-	1	4	3	3	43
<i>Quadrula nodulata</i> (Rafinesque, 1820)	-	-	-	1	-	-	2	-	-	-	-	-	3
<i>Quadrula cylindrica</i> (Say, 1817)	-	-	-	-	-	-	-	-	1	-	-	-	1
<i>Quadrula quadrula</i> (Rafinesque, 1820)	4	2	2	3	5	1	2	3	3	1	3	-	29
<i>Tritogonia verrucosa</i> (Rafinesque, 1820)	-	-	-	-	-	-	-	-	-	-	3	-	3
<i>Plectomerus dombeyanus</i> (Valenciennes, 1833)	-	-	-	-	-	-	-	-	-	-	1	1	2
<i>Elliptio dilatatus</i> Rafinesque (1820)	-	-	-	-	-	-	-	-	-	2	-	-	2
<i>Anodonta grandis</i> Say (1829)	-	-	-	-	-	1	-	-	1	1	-	-	3
<i>Obliquaria reflexa</i> Rafinesque (1820)	-	-	-	-	-	-	-	-	1	1	-	-	2
<i>Obovaria olivaria</i> (Rafinesque, 1820)	-	-	-	-	-	-	1	-	2	-	-	-	3
<i>Truncilla truncata</i> Rafinesque (1820)	-	-	-	-	-	-	-	-	-	-	1	-	1
<i>Leptodea fragilis</i> (Rafinesque, 1820)	-	-	-	2	1	3	2	1	6	-	-	-	15
<i>Lampsilis anodontoides</i> (Lea, 1831)	-	-	-	1	-	-	-	-	-	-	2	-	3
<i>Lampsilis ovata ventricosa</i> (Barnes, 1823)	-	-	-	-	-	2	-	1	1	-	2	-	6
Total number of specimens:	18	5	15	15	16	12	19	9	19	10	15	6	159
Total number of species:	4	3	3	6	4	6	6	4	10	6	7	4	17
Bivalvia: Corbiculidae													
<i>Corbicula cf. fluminea</i> (Müller)	27	81	2	4	2	1	15	1	-	-	1	34	168
Gastropoda: Viviparidae													
<i>Campeloma</i> sp. (probably <i>subsolidum</i>)	-	-	-	-	-	-	2	-	-	-	-	4	6
<i>Viviparus subpurpureus</i> (Say, 1829)	-	-	-	-	-	-	-	-	-	-	-	23	23
Total number of all mollusk specimens:	45	86	17	19	18	13	36	10	19	10	16	67	356
Total number of all mollusk species:	5	4	4	7	5	7	8	5	10	6	8	7	20

niques described elsewhere (Kraemer, 1976). Substrate particle size using the Wentworth scale (Wentworth, 1922), artifacts and shell fragments encountered in the substrate were tabulated for each lot of the samples. All visible organisms, many only 1-2 mm long, were saved. Specific determinations of the mollusks were made insofar as possible. Other organisms, because of their lesser value to the limited aims of this study, were seldom evaluated beyond family or order.

All items retrieved from crowfoot dredge and ponar grab samples were accessioned into the University of Arkansas Museum Collections.

RESULTS

Crowfoot dredge samples

Table 2 summarizes most of the findings from study of the 12 sample series. Though *Proptera capax* was not found, a diverse fauna of other mussel species was present. The mussels included 17 species, six of which are in the same subfamily as *P. capax*: *Obliquaria reflexa*, *Obovaria olivaria*, *Truncilla truncata*, *Leptodea fragilis*, *Lampsilis anodontoides* and *Lampsilis ovata ventricosa*. Mussels from the crowfoot dredge samples represented a mature, long-established group of animals, ranging in age from six to more than 25 years.

A substantial biomass of the introduced bivalve, *Corbicula fluminea* (Sphaeriacea: Corbiculidae), also appeared in the crowfoot dredge samples. The animals were at the upper limit of their known size range, from

8.7-56.3 mm long, with a mean of 39.0 mm. From two of the 12 sample series the gastropods *Campeloma* (probably *C. subsolidum*) and *Viviparus subpurpureus* were recovered.

Ponar grab samples

Numbers and kinds of animals recovered from the 47 stations and 77 lots of ponar grab samples from the four river transects at the bridge site are shown in Table 3. A preponderance of mollusks was found, but insect forms, mostly larvae of Chironomidae and Trichoptera, and occasional specimens of other animal groups were also present.

C. fluminea was the most common bivalve mollusk found in the ponar samples. This species was represented by adults, juveniles (1-4 mm long), and by abundant shell fragments. Indigenous relatives of *C. fluminea* included *Musculium transversum* (Sphaeriacea: Sphaeriidae) and were found in only five of the samples, mostly near shore. Unionid bivalves were represented by occasional shell fragments, a few of which could be identified as *Quadrula pustulosa*, *Q. quadrula* and *Leptodea fragilis*. The only identifiable whole juvenile mussel specimen found was *Quadrula cylindrica*.

Gastropods were a prevalent component of the ponar samples. At 23 of the 47 stations, *Viviparus subpurpureus* was present. Thirteen of the ponar sampling sites yielded specimens of *Pleurocera canaliculatum*; and 9 stations included *Campeloma subsolidum*. Both *V. subpurpureus* and *C. subsolidum* were present as large adult snails (2 cm+ tall) and less frequently as juveniles. Rarely encountered were *Somatogyrus*,

TABLE 3
ORGANISMS COLLECTED BY PONAR GRAB
FROM FOUR BENTHIC TRANSECTS OF THE WHITE RIVER, ST. CHARLES, ARKANSAS, NOVEMBER 21 AND 26, 1979

Transect 1

Station	A	B	C	D	E	F	G	H	I	J	K	Total
<i>Corbicula</i> cf. <i>fluminea</i> (Müller)	30	66	19	2		2	1					120
Unidentified juvenile Unionidae						1						1
Juvenile <i>Quadrula cylindrica</i> (Say)			1									1
<i>Viviparus subpurpureus</i> (Say)	6	10	2		1	1						20
<i>Pleurocera canaliculatum</i> (Say)	1	1	1									3
Chironomidae		22	61	1	4	5	1	1				95
Trichoptera	2											2
Coleoptera			1									1
Oligochaeta	3	115	1		1							120
Nematoda	2											2
Number of specimens	44	215	85	3	6	9	2	1	0	0		365
Number of taxa	6	6	6	2	3	4	2	1	0	0		10

Transect 2

<i>Corbicula</i> cf. <i>fluminea</i> (Müller)	32	27		40	2	4		2	10	12		129
Unidentified Sphaeriidae					2							2
<i>Viviparus subpurpureus</i> (Say)	24	2		14	3			1	4	13		61
<i>Campeloma</i> (probably <i>subsolidum</i>)	2								3	4		9
<i>Somatogyrus</i> sp.					1							1
<i>Pleurocera canaliculatum</i> (Say)	6	1		2					1			10
<i>Goniobasis potosiensis plebeius</i> (Anthony)					1							1
Chironomidae	1			3	4	11		5	6			30
Trichoptera	12					1						13
Plecoptera	2											2
Ephemeroptera		1										1
Amphipoda	5											5
Oligochaeta	1											1
Nematoda						1						1
Number of specimens	85	31	0	59	13	17	0	8	24	29		266
Number of taxa	9	4	0	4	6	3	0	3	5	3		14

Transect 3

<i>Corbicula</i> cf. <i>fluminea</i> (Müller)	13	5	53	5	7	2			5	3	57	150
<i>Musculium transversum</i> (Say)	1								1	1		3
<i>Viviparus subpurpureus</i> (Say)		2	8	1	1				3		11	26
<i>Campeloma</i> (probably <i>subsolidum</i>)	6		1	1							1	9
<i>Somatogyrus</i> sp.			1		1							2
Unidentified Hydrobiidae			1									1
<i>Pleurocera canaliculatum</i> (Say)	1	2	4								1	8
Chironomidae	1		8	3		1		2		5		20
Trichoptera		5										5
<i>Palaemonetes kadiakensis</i>		1										1
Amphipoda	1	5	1									7
Oligochaeta	4	5	16		1	1					3	32
Nematoda			3					2	1			6
Number of specimens	27	25	96	10	10	6	0	4	10	9	73	270
Number of taxa	7	7	10	4	4	3	0	2	4	3	5	13

Transect 4

<i>Corbicula</i> cf. <i>fluminea</i> (Müller)	10	21	122	5	6	6	1		1	7		179
<i>Musculium transversum</i> (Say)			1									1
<i>Quadrula pustulosa</i> (Lea)									1			1
<i>Quadrula quadrula</i> (Rafinesque)									1			1
<i>Leptodea fragilis</i> (Rafinesque)		1										1
Unionidae fragments									4			4
<i>Viviparus subpurpureus</i> (Say)	2	4	14			3			4	1		28
<i>Campeloma</i> (probably <i>subsolidum</i>)									1			1
<i>Pleurocera canaliculatum</i> (Say)	1	3	9									13
<i>Physa</i> sp.							1					1
Chironomidae	2	3	17	21	9	2	5	6	2	1		68
Trichoptera	4								2			6
Dytiscidae									3			3
Oligochaeta		2			3	1						6
Hirudinea	1	1										2
Nematoda					2	5						7
Turbellaria									3			3
Number of specimens	20	35	163	26	20	17	7	6	22	9		325
Number of taxa	6	7	5	2	4	5	3	1	10	3		17

Goniobasis and a hydrobiid snail. Larger average size and lesser numbers of gastropods approached but did not equal the biomass of *C. fluminea* in the ponar samples.

Samples comprised of just fine and medium sand substrate usually yielded nothing more than juvenile *C. fluminea* and a few midge larvae (Chironomidae); substrate samples comprised of very coarse sand, granules and cobbles frequently contained species of insect larvae, gastropods, and *C. fluminea*.

Simple, graphic comparison of the mollusk communities sampled by means of crowfoot dredge and ponar grab, is shown in Figure 1.

DISCUSSION

Combined results of crowfoot dredge and ponar grab sample studies allow us to characterize the community structure of the river bottom. Major components of the benthos are not mollusks and arthropods, as found for the Arkansas River (Kraemer, 1976), and characterized as typical for many rivers (Hynes, 1972). The White River benthos proved in this study to be comprised primarily of two groups of mollusks: (1) bivalves, especially indigenous mussels (Unionidae) and the introduced Asian clam *Corbicula fluminea* (Corbiculidae); and (2) gastropods, especially *Viviparus subpurpureus*, *Pleurocera canaliculatum* and *Campeloma subsolidum*. Indigenous mussels recovered in this study (nearly all by crowfoot dredge) were almost all more than six years old. Since seasonal sampling was not done, we are not sure that younger mussels are not now present, though it seems unlikely.

Prior to 1966, chief molluscan inhabitants of the river bottom most likely were indigenous mussels, including *Proptera capax*, and indigenous snails such as the species mentioned above. Several large commercial shell heaps near the White River at Devalls Bluff, about 20 miles upstream from the bridge site at St. Charles were inspected in 1966. While *P. capax* was present, there was no evidence of *C. fluminea*. Since 1966, the introduced *C. fluminea* has established itself among the long-lived, large benthic animals (retrieved in crowfoot dredge samples) and among the small benthic animals (retrieved in ponar grab samples).

Evidence presented here indicates that the size of *Corbicula*, both as a juvenile and as a relatively long-lived adult, may be a factor in its phenomenal "success" as it populates U.S. river bottoms. Previous studies have indicated that mature *C. fluminea* has peculiar structural, functional and behavioral characteristics (Kraemer, 1979b, 1978a, 1978b, 1977a) which suit it for life on a disturbed river bottom among indigenous mussels. Less attention has been given to the role of immature *C. fluminea* among indigenous small benthic animals (Kraemer, 1979a, 1977b). Went (1968) reminds us that extremes of size impose very different living conditions on organisms. *C. fluminea* seems to have met successfully the living conditions imposed on both of its size extremes and thereby to have outclassed the capabilities of its indigenous benthic molluscan neighbors, both large and small.

ACKNOWLEDGEMENT

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A NEW AID TO TAXONOMIC RESEARCH ON MOLLUSKS

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Taxonomic studies on mollusks are impeded by a major problem concerning the literature of the latter half of the 19th Century. There are virtually no exhaustive indices to the literature of the period 1850-1870. Sherborn's magnificent "Index Animalium" (1902-1933) covers years 1758-1850. The Zoological Record began abstracting literature in 1864 and continues to date, although the latter was rather incomplete during its

early years. Therefore, for the 20 year period, 1850-1870, it has been a problem of "hunting and hoping" that references are not missed.

In 1972, in response to our suggestion, Florence A. Ruhoff undertook the compilation of an "Index to the Species of Mollusca Introduced in 1850-1870". It is now in press at the Smithsonian. Florence completed the manuscript in 1976 and then retired having spent about 5 years compiling the data for it. Those of us who remained in Mollusks at the Smithsonian have come to know the Index quite intimately since we have shepherded it through the publication process. Several months were spent recently proofreading the 1,093 long galley proofs which resulted from the 3,000 page manuscript.

Some statistics concerning the Index follow. It consists of 3 parts: a bibliography to the literature on Recent and Fossil Mollusks for 1850-1870 of almost 4,000 titles; a species index to the new trivial taxa introduced, which exceeds 32,000 entries and, serving as access to the latter, a generic index which groups the trivial names according to the genera under which they were introduced. The format, therefore, is similar to that of Sherborn's Index.

The bibliography contains multiple pages of entries for the following authors, and I mention only a few of the larger contributors: Thomas Bland, J.G. Cooper, H. Crosse, G.P. Deshayes, Paul Fischer, Sylvanus Hanley, H.C. Kuster, E. von Martens, O.A.L. Mörch, A. d'Orbigny, L.

Pfeiffer, R.A. Philippi, C.A. Recluz, L. Reeve, The Sowerbys, G.W. Tryon, and many others.

This was a really enormous task, but Florence Ruhoff welcomed a big challenge. The Index will be a monument to her bibliographic skill—the largest of the several such tasks she did so well such as "The Zoological Taxa of W.H. Dall" (Boss, et al., 1968) and a "Bibliography and Taxa of Paul Bartsch" (Ruhoff and Rehder, 1973).

We recognize that there are omissions and errors in the work. Even Sherborn had them. We will welcome your pointing these out to us since we plan to publish supplements at later dates.

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ABSTRACTS OF PAPERS PRESENTED AT THE 1980 MEETING

GASTROPODS SYMBIOTIC WITH ZOANTHINARIAN SEA ANEMONES

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ABSTRACT

Nearly all the living orders of benthic coelenterates have gastropods symbiotic with them. Sixteen gastropod species (fifteen of them prosobranchs) are known with the Zoanthinaria: three epitoniids (*Epitonium millecostatum* (Robertson, in press) and *Graciliscala* spp. (Masahito & Habe, 1976), nine architectonicids (all in the genus *Heliacus* (Robertson, 1976; Marche-Marchal, 1969), three coralliophilids (*Coralliophila* spp. (Robertson, in press) and one aeolidiid nudibranch (*Aeolidiopsis ransonii* Pruvot-Fol, 1956). *Heliacus* and *Aeolidiopsis* seem to be genera specific to zoanthinarians. The species of *Graciliscala* occur with *Epizanthus*, and the others with *Palythoa* or *Zoanthus*. Eleven of the symbionts are Indo-West-Pacific in distribution.

Zoanths have nematocysts and zooxanthellae in their tissues. *Palythoa* also has sand grains. At least one species of *Palythoa* has in it a toxin that is lethal to mammals at low concentrations (Moore & Scheuer, 1971). When they feed on *Palythoa*, *Heliacus* and *Aeolidiopsis* ingest and digest host tissues. By contrast, *Epitonium millecostatum* and *Coralliophila clathrata* ingest and digest *Palythoa* mucus (containing sloughed off nematocysts and zooxanthellae). *Heliacus* and *Aeolidiopsis* defecate sand grains (and *Heliacus*, also remnants of zooxanthellae). By contrast, *Epitonium* defecates mainly discharged nematocysts (holotrichous isorhizas), and *Coralliophila* remnants of zooxanthellae (Robertson, in press).

The gastropods with zoanths occur at low densities and competition between the different taxa seems unlikely; nevertheless, these symbionts divide their resource by ingesting and/or digesting different components of their hosts.

NAIAD MOLLUSKS AND CHANNEL ALTERATIONS: A SURVEY OF THE LOWER SAINT FRANCIS RIVER, ARKANSAS.

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ABSTRACT

Between 1964 and 1978 collections were made from 33 different sites on the lower 150 miles of the St. Francis River system. Only 32 of the 42 species of naiades recorded to date still survive in the altered river. Nine of the 29 species reported by Call (1895) were not found.

FEEDING, AGONISTIC, MATING AND EGGLAYING BEHAVIOR OF A PHILIPPINE CUTTLEFISH, *SEPIA BANDENSIS* ADAM 1939

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ABSTRACT

Observations of feeding, agonistic, mating, and egg-laying behavior of

Sepia bandensis were made aboard the R/V ALPHA HELIX in November 1979. About 50 animals weighing 20-35 g and having mantle lengths of 50-60 mm were available for study. An unusually large male weighed 48 g and measured 70 mm in mantle length. Behavior was recorded on both color and black and white 35 mm film.

For prey capture the tentacles were used in the manner described for other *Sepia* species. One crab taken away from a cuttlefish five minutes after capture had a bite mark at the base of the fifth leg and had been paralyzed.

Agonistic behavior of males began with color and posture displays and ended in a contest of strength with one animal attempting to push the other to the substratum. Pushing was accomplished by one animal lying over the other at the anterior margin of the mantle with its body perpendicular to the lower animal. The upper animal blew jets of water towards the surface attempting to force the lower one down; the bottom animal blew jets of water down attempting to force the upper one up. Contests ended when an animal was forced either to the bottom or surface. The loser signaled its defeat by changing color and avoiding the winner. Neither biting nor use of the suckers was observed during agonistic behavior.

Mating occurred whenever a male and female were placed together in a tank. As many as 14 consecutive matings were observed between one pair during a 15-min period. Males used the fourth left arm to transfer spermatophores.

Egg laying of two females was observed closely. Females held an egg in the arms, covered it with layers of black coating, and attached eggs to an over-hanging rock at 5-min intervals. One female laid 22 eggs in a 2-hour period. Eggs were laid in a cluster and each egg measured approximately 14 x 12 mm exclusive of the attachment stalk.

RAFINESQUE - COLLECTING AT THE FALLS OF THE OHIO

J.P.E. Morrison
Washington, D.C.

No Abstract Submitted

MUSSELS (NAIADES) OF THE LITTLE BLACK RIVER BASIN IN MISSOURI AND ARKANSAS

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ABSTRACT

A field survey, conducted during July 16-27, 1979, of the mussel (naiad) fauna at 26 sites in the Little Black River Basin in Arkansas and Missouri revealed a total of 36 species. All 36 species were found in the Little Black River; 12 were found in Beaverdam Creek, 15 in Logan Creek, and 5 in Harris Creek. Seven species, *Pleurobema coccineum* (17.0%), *Fusconaia flava* (16.4%), *Lampsilis reeviana brevicula* (15.5%), *Elliptio dilatata* (11.4%), *Villosa lienosa lienosa* (6.4%), *Actinonaias ligamentina carinata* (6.0%), and *Quadrula pustulosa* (4.1%) comprised 76.8% of the living naiades found in the Little Black River Basin.

Two species found, *Epioblasma florentina curtisi* and *Lampsilis orbiculata*, are listed as endangered on the United States List of Endan-

gered and Threatened Wildlife and Plants, and seven species found, *Arcidens confragosus*, *Cyprogenia aberti*, *Fusconaia ebena*, *Plectomerus dombeyana*, *Potamilus purpuratus*, *Toxolasma lividus glans*, and *Villosa lienosa lienosa*, are listed as rare or endangered in Missouri. The Little Black River between miles 33.6 and 38.5 provide important habitat for *E.f. curtisi* and the downstream 9.1 miles of the Little Black River may provide important habitat for *L. orbiculata*.

A LONG LOST (EXTINCT?) MOLLUSC OF THE OHIO RIVER

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ABSTRACT

In 1818, an unusual person, Constantine Samuel Rafinesque, about 35 years old at the time, went on a walking tour, (*Chronica Botanica* 8 (2): 291-360. 1944.) He crossed Pennsylvania, caught a boat at Pittsburgh, and cruised down the Ohio River. On this trip he visited Louisville, and also spent several days with John James Audubon at Hendersonville. Audubon found Rafinesque to be such a strange fellow that he played practical jokes on him. It could be that the jokes were to repay Rafinesque for demolishing Audubon's fine Cremona violin while chasing a bat. There were a number of these practical jokes - animals that Audubon described to Rafinesque, but which were not real - and Rafinesque was gullible enough to believe the stories.

Rafinesque was not an ignorant man, but was in fact a sophisticated and well-published scientist of the day. At a time when travel was still difficult, he crossed the Atlantic three times. He arrived in America the second time with an enormous collection of molluscs as well as books, manuscripts, maps, and a botanical collection. This was all lost in shipwreck, and, in fact, he lost almost everything he owned.

Rafinesque had recovered from the disaster by 1818. He had a wonderful time traveling down the Ohio, for it seemed that everything was new and underscribed. He began a manuscript on the fishes of the Ohio, and his new friend Audubon helped him with descriptions of fish that Rafinesque hadn't seen for himself. There are ten of these fictitious fish in his monograph, otherwise a well written work for the time.

Audubon also helped Rafinesque with the description of a mollusc that lived on rocks at the bottom of the river (Binney and Tryon, 1864. The complete writings of Constantine Smaltz Rafinesque, on recent and fossil Conchology. 1-96, 1-7, 3 pls. Bailliere Brothers, New York. "I have not seen the living animal myself; but Mr. Audubon of Hendersonville, a zealous observer, has drawn it, and it appears to have a head with two eyes and no tentacula jutting out of the perforation", Rafinesque reported. He was so overcome with this strange animal that he described it as a brachiopod and named it *Notrema fissurella*. Two years later he gave it a new name, calling it *Tremesia patelloides*, and described it as a trivalve intermediate between the brachiopods, the shipworms, and the patellas. The former name he dismissed as, "the false name *Notrema*".

This second name and description is found in the supplement Rafinesque's monograph of the freshwater bivalves of the Ohio River. The animal is entirely imaginary, concocted by Audubon, and is almost forgotten. It is unfortunate that Rafinesque included these mythical animals in his monographs because it gave him a reputation, for the most part undeserved, of doing poor work. It is hard to defend him, however, since, even in those more carefree times, one was supposed to investigate carefully a new plant or animal before introducing it to the scientific world.

CORRELATIONS OF SHELL MEASUREMENTS, SEX, AND TREMATODE INFECTION IN *TAREBIA GRANIFERA* IN TEXAS.

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Pace (1973, *Malcol. Rev.*, Suppl. 1, 6:1-118) and other authors reported the Thiaridae as parthenogenetic with no males in *Tarebia granifera*. Scates, Matthes, Blystone, and Murray (1977, *Bull. Am. Malcol. Union*, p. 89) first documented spermatogenesis in *T. granifera* at the electron microscopic level. They erroneously proposed that the seminiferous tubules were associated with ovarian tissue.

We examined 1000 *T. granifera* from south Texas, of which 4.7% were males, 68.4% were females, and 26.9% had no discernible gonad. Females had a yellowish ovary following the columellar aspect of the golden-brown digestive gland which occupied the apical three shell whorls. Males had reddish testicular tissue which occupied varying portions of the digestive gland so that little gland tissue was seen in same. No specimens had both ovarian and testicular tissue. Typical spermatogenesis of eupyrene sperm was seen, and all males had both motile eupyrene and oligopyrene sperm. Tripolar metaphase configurations and telophase stages having chromosomes in the cytoplasmic bridges between daughter cells were present.

Shell lengths, diameters, and length/diameter ratios were correlated to sex and to infection with rediae of *Philophthalmus gralli*. An analysis of variance showed that (1) the diameter of male shells was significantly smaller than that of female shells ($P < 0.05$); (2) the length/diameter ratio of male shells was significantly larger than female shells ($P < 0.01$); (3) the shell lengths and diameters of infected snails were significantly larger than those of uninfected snails ($P < 0.01$). No males were infected and statistical analysis suggested the possibility of parasitic castration of females.

The percentage of *T. granifera* males in Texas is higher than previously recorded for thiarids. *T. granifera* is not a simultaneous hermaphrodite, but might undergo sex reversal or be dioecious. The irregular karyokinesis and the tripolar metaphase stages observed suggest that *T. granifera* males are autoallopolyploids, hence asexual. The observation of motile eupyrene sperm implies sexual reproduction. The occurrence of these two phenomena in the same specimens seems contradictory, and indicates that reproduction in thiarids is more complex than previously reported.

REDISCOVERY OF "AMNICOLA" DESERTA PILSBRY (MOLLUSCA: GASTROPODA) AND TWO NEW UNDESCRIBED HYDROBIOID GASTROPODS FROM THE VIRGIN RIVER DRAINAGE, UTAH-ARIZONA

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Since its description, the exact locality for "*Amnicola*" *deserta* Pilsbry 1916 has remained unknown to malacologists. Populations of "*A.*" *deserta* now have been found in desert springs located in Washington, Middleton, and St. George, Washington County, Utah. In all, seven springs have been discovered that support populations of this species. West Middleton Spring contains a population that morphometrically resembles the type collection from the Academy of Natural Sciences of Philadelphia.

During the investigation two closely related hydrobioid gastropod species have been discovered in the Virgin River drainage, Utah-Arizona. One undescribed species was found in five springs near Littlefield, Mohave County, Arizona. The other species was found in five scattered

spring areas north and east of "Amnicola" desert populations, including Grapevine Spring, Zion National Park, Utah. Water developments threaten many of these springs with extinction.

A MOLLUSCAN FAUNA AND HABITAT STUDY VIS-A-VIS THE ENDANGERED SPECIES LAW

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ABSTRACT

Putative presence of the endangered species, *Proptera capa*, necessitated a benthic survey prior to construction of a large bridge and approaches over the White River, St. Charles, Arkansas. Corroborative sampling with bail and grab revealed a "mollusk-mollusk" community but no *P. capax*. Certain problems, ironies and possible protocol schema that emerged from this study were discussed.

OBSERVATIONS ON LANDSNAILS IN LABORATORY COLONIES

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ABSTRACT

Observations on the colonies were made while obtaining data on growth rates and clutch production for several species of landsnails. Preliminary observations on the effects of density on juveniles, feeding behavior in *Euglandina rosea*, and the use of body pigmentation patterns to aid in identification of juvenile specimens seem worthy of further pursuit and are summarized below.

No clear demarcation between low density and high density (crowded) was determined during the observation period, thus the terms are applied in a general sense. Young reared in crowded colonies were stunted in growth, often not attaining adult size, shell form or maturity regardless of their age. Young reared in high densities were also more aggressive than young reared in low density colonies as indicated by the frequent occurrence of cannibalism and shell chewing (producing rough scarred shells on the victims) during the first 6 months. The inhibitory effects of crowding are irreversible if density does not decrease before a critical, but as yet unmeasured, period of time elapsed. These effects of high density were observed in colonies of *Mesodon thyroidus*, *M. perigraptus*, *Mesomphix globosus*, *Polygyra avera*, *P. cereolus*, *P. septemvoluta*, *Stenotrema floridense*, *Triodopsis albolabris major* and *T. hopetonensis*. It also appears that too low of a density may have as negative an effect on the young snails as too high a density, especially in the *Polygyra* where isolates did poorly compared to groups of 2 or 3 young all in equal sized containers.

The carnivorous *Euglandina rosea* is an ideal subject for studies on the tracking, apprehension and consumption of prey species, size preference in prey selection and avoidance reactions of the prey. Distinct behavioral patterns are displayed by *E. rosea* individuals as they follow the mucous trail of the prey, when they catch and examine the prey and when they immobilize the prey before feeding. Also, it is possible that cannibalism among the young of a clutch is inhibited during the first 4-6 weeks after hatching.

It was also noted that body pigmentation patterns, easily seen through the thin shell of juveniles, were distinct for each of the 9 species observed. Further documentation of these patterns and their range of variation could prove useful in identifying juveniles of different species with similar looking shells.

THE WHITE RIVER: DEGRADATION OF A MOLLUSCAN HABITAT.

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ABSTRACT

The White River of Arkansas and Missouri was formerly a very important habitat for freshwater Mollusca. Reservoir construction and channelization have altered the basin extensively. Remnants of the fauna in the headwaters and tributaries persist but are threatened. Small commercial operations remain active in the lower portion of the river.

REPRODUCTION OR SHELL ARMOR - A TRADE OFF IN FRESHWATER GASTROPODS

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ABSTRACT

Among five gastropod species *Physa heterostrophus* (Say), *Bithynia tentaculata* (Linnaeus), *Helisoma trivolvis* (Say), *Mudalia carinata* (Bruguiere), and *Goniobasis virginica* (Gmelin), found in the Potomac River at Great Falls, Virginia there is a hierarchy in the ability to withstand both crayfish and duck predators that assault the shell. The same sequence of snails that exhibits a progressively greater defense also exhibits constantly reduced growth rates and reproductive efforts. *Mudalia* and *Goniobasis* with greatest predator resistance had the longest times to maturation in the field, the lowest reproductive efforts and the lowest intrinsic rates of increase among the snail species. In contrast, the most vulnerable species, *Physa*, exhibited the most rapid population expansion and maturation rate. *Bithynia* and *Helisoma* were intermediate in both reproductive efforts and intrinsic rates of increase and were also intermediate in predator susceptibility.

THE GENUS CORBICULA MUHLFELD (BIVALVIA: CORBICULIDAE) IN AFRICA AND SOUTH AMERICA: ZOOGEOGRAPHIC AND TAXONOMIC PROBLEMS

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ABSTRACT

Zoogeographic records from museums around the world were examined for species of *Corbicula* collected in Africa and South America. The synonymy used by the Academy of Natural Sciences, Philadelphia was used to reflect current taxonomic conventions for the genus used by a major collection. Seventeen species of *Corbicula* were found for Africa: *C. aegyptica* Bogart, *C. africana* Kiawis, *C. agensis* Kurr, *C. artini* Pallary, *C. astartina* Martens, *C. australis* (Lamarck), *C. cunningtoni* Smith, *C. fischeri* Germain, *C. fluminea* (Müller), *C. kirkii* Prime, *C. lamarckiana* Prime, *C. oliphantensis* Craven, *C. pusilla* (Philippi), *C. radiata* Hanley, *C. sikarae* Ancey, *C. subradiata* Kurr and *C. tanganyicensis* Crosse. Twenty species were found for South America: *C. amazonica* (Anthony), *C. arcata* Deshayes, *C. brasiliensis*, *C. coloniensis* Pilsbry, *C. compacta* Marshall, *C. cuneata* Jonas, *C. delicata* Marshall, *C. feissieri* Marshall, *C. filipponei* (Marshall), *C. fonteneli*, *C. fortis* Marshall, *C. limosa* (Maton), *C. obsoleta* Deshayes, *C. pampeana*, *C. paranensis* (Orbigny), *C. radiata* Hanley, *C. rotunda* Prime, *C. simplex*, *C. straminea* and *C. variegata* Orbigny. Records for *C. agensis* in Ghana and *C. australis* in South Africa are doubtful due to their respective Indian and Australian distribution, although both species may have been intro-

duced. Nearly every African record of *Corbicula* spp. occurred between 26°E and 34°E. Six of the species reported in Africa were collected near Cairo and Alexandria, Egypt. African species were generally found at elevations between 0 and 1500 m and predominant substrata were sandstone, shale or schist. Environmental factors which may influence the distribution of *Corbicula* spp. are mean annual rainfall above 180 cm/yr. and the closed tropical forest vegetation of the Congo River drainage.

Thirteen of 20 *Corbicula* spp. reported in South America were collected within a 250 km radius of Buenos Aires, Argentina and are concentrated in the La Plata, Parana and Uruguay drainages. The collection concentrations may be the result of expeditions concentrating in the areas and therefore may not represent the true distribution of *Corbicula* spp. on both continents.

COMPLETE LIFE-CYCLE OF *CAMPELOMA DECISUM* SNAILS IN THE LABORATORY

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ABSTRACT

Campeloma decisum grew consistently well when clam or fish food was provided with a substrate of sand or mud. Food alone, or the substrate alone was generally ineffective in promoting growth. A population of newborn snails gave rise to three generations.

MORPHOLOGY OF THE TALON IN THE LAND SNAIL, *TRIODOPSIS MULTILINEATA*

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ABSTRACT

The talon of Nebraska specimens of *Triodopsis multilineata* is a discrete projection from the region of junction of the little hermaphroditic duct, the albumen gland, and the spermiduct. Its form varies from globose to digitiform, depending on activity state. Its principal components are a strongly ciliated fertilization chamber and a cluster of bulbous, non-ciliated sperm storage chambers which arise from a basal group of slender ducts which converge to join the base of the fertilization chamber just proximal to the entry of the little hermaphroditic duct. The common, basal duct of the talon is strongly ciliated in the region of its broad junction with the duct of the albumen gland and the spermiduct.

The proximal part of the little hermaphroditic duct in *Triodopsis multilineata* is delicate, with a ciliated lining, rather than strongly muscular as it is in the corresponding region in *Anguispira alternata*.

SYSTEMATICS, ANATOMY AND BIOLOGY OF *CAMPANILE* *SYMBOLICUM*, A RELICT CERITHIACEAN SNAIL.

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ABSTRACT

Campanile symbolicum is the sole survivor of a long lineage of large snails well represented in the Tethys Sea during the Tertiary. Anatomical features place it in the Cerithiacea, but in a separate family, Campanilidae. Unique features are a short bipectinate osphradium, a seminal receptacle in the pericardial sac, and esophageal pouches.

IN SITU BEHAVIORAL OBSERVATIONS OF CEPHALOPODS AT GRAND CAYMAN, B.W.I.

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ABSTRACT

Four trips were made to Grand Cayman between 1974 and 1980 to observe cephalopods in their natural habitat. Observation were made during the day and at night along the northwestern and western sides of the island utilizing open and closed circuit SCUBA and snorkeling. At night, spotlights were used by divers to locate foraging cephalopods, and observations were made with dim lights or none at all. Cephalopods were also attracted to bright night lights positioned either on the surface (500 watt quartziodide) or underwater (1000 watt mercury vapor). *Octopus briareus* was found only at night foraging on the forereef in water depths of 10 to 20 m. They made speculative attacks on small rocks and coral heads and captured small crabs and shrimps. Large adults were seemingly oblivious to a diver's presence and continued to forage and feed. Home sites were not observed. *Octopus vulgaris* was observed only in shallow (0.3 to 5.0 m) backreef areas where scattered rubble, coral heads and seagrass were found. They were mostly nocturnal, but they were also observed in early morning and late afternoon. They lived in naturally occurring holes around which they deposited empty bivalve and xanthid crab shells from prey captured in the surrounding area. Some octopuses were seen in the same hole for up to four days, while other holes contained a different octopus every night. Very small individuals of *Octopus defilippi* (previously referred to as "Macrotritopus larvae") were observed singly in the plankton around underwater night lights positioned over the deep forereef. Feeding was not observed in the field, but in the laboratory they fed on an assortment of small fiddler crabs and palaemonid shrimps. Very small individuals of *Octopus burryi* were collected from the 1000 watt mercury vapor underwater light positioned on the forereef at a depth of 20 m. They were not planktonic but had simply crawled onto the light itself from the adjacent coral reef bottom. Small individuals transported to the laboratory fed on small fiddler crabs and palaemonid shrimps. The tropical arrow squid *Loligo plei* was seen only at night over the forereef in depths of 15 to 25 m. Schools of up to 100 were attracted to the vicinity of surface and underwater night lights. They preferred to stay on the periphery of the lighted area and would make forays near the bright light to feed on planktonic organisms and small fishes. They were never seen over the same reef areas during the day, when they presumably move to deeper water. The reef squid *Sepioteuthis sepioidea* was observed commonly at night over the forereef either alone or in groups of two to five. During the day they were seen commonly over the backreef areas in schools of 5 to 20 squids. Feeding was not observed. A few individuals of the oceanic squid *Abralia veranyi* were observed in the vicinity of underwater night lights positioned on the forereef at 20 m depth. They appeared to be feeding on plankton accumulated around the lights. This species is generally an open ocean form and the night lights probably attracted it from nearby deep water. In general, Grand Cayman has a fairly rich cephalopod fauna that should be investigated further.

THE ULTRASTRUCTURE OF THE DERMAL LEUCOPHORES OF *OCTOPUS DOFLEINI*.

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ABSTRACT

The integumental white spots of *O. dofleini* consist of dense concentra-

tions of leucophores subjacent to the chromatophore layer. Each leucophore cell approximates a compressed ellipsoid and is disposed with its broad plane parallel to the surface of the integument. Thousands of ovoid organelles, the leucosomes, protrude from the leucophore. The peripheral field of leucosomes diffusely reflects incident light.

FUNCTIONAL MORPHOLOGY OF SQUID ARMS AND TENTACLES.

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ABSTRACT

Preliminary histological work has shown the arms and tentacles of squid to possess an unusual morphological arrangement for skeletal support. These appendages lack the hardened internal and external skeletal elements of fluid-filled cavities (hydrostatic skeletons) which are typical of most other organisms. Instead, squid may use an unusual muscular array for support.

FACTORS AFFECTING THE DISTRIBUTION OF *OCTOPUS JOUBINI* IN THE FIELD.

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Waltham, MA

ABSTRACT

Individual *Octopus joubini* in St. Joseph Bay, Florida were neither spaced nor grouped. They did not stay long in the same area and did not leave when artificially crowded. Their preferred food was abundant. They were somewhat affected by the distribution of mollusc shells which provided shelter on the sandy beaches.

THE REARING AND MAINTENANCE OF *OCTOPUS BRIAREUS* IN THE LABORATORY WITH ASPECTS OF THEIR BEHAVIOR AND BIOLOGY

Martin R. Wolterding

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ABSTRACT

Five individuals of *Octopus briareus* Robson from South Florida, were hatched from eggs and laboratory reared to sexual maturity and fertile-egg laying. This species displayed a wide range of body patterns. The chronic general mottle, a long lasting cryptic pattern, was the most commonly observed. The acute body patterns, which are responses to stimuli of short duration, included the uniform dark phase, acute mottle, dymanic display and the unilateral effect.

A wide range of body patterns and postures were closely associated with specific aspects of their behavior. Three distinct methods of attacking prey organisms were observed, the parachute, side-arm and pincer attack. Each method was accompanied by an associated body pattern and maneuver. *Octopus briareus* produced an intra-specific display, the played arm posture with passing cloud, which appeared to be related to the establishment of a dominance hierarchy based upon size.

Copulation was first observed among two 209 day old animals. The female was able to store viable sperm for up to 100 days. About a month before egg laying, the female gathered shells and stones to build a den for brooding. Once the den was complete, the female stopped feeding. This species laid up to 500 eggs measuring 4 x 11 mm; they hatched in 60 to 80 days.

Newly hatched *O. briareus* are benthic, and are able to crawl, swim and produce ink. They have two sets of chromatophores which enable them to change color as rapidly and completely as the adults.

The *Octopus briareus* were reared primarily on crabs, although they accepted a wide range of food organisms including polychaetes, fish, crustaceans, and molluscs. They refused all bivalves, gastropods and echinoderms. The animals grew to maximum size in about 240 days, the males grew at a more uniform rate than the females. Average life span was 350-410 days with one male surviving 500 days.

CEMENTATION IN THE EARLY DISSOCONCH STAGE OF *CRASSOSTREA VIRGINICA*

Christian Tomaszewski

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ABSTRACT

The ultrastructure and histochemistry of the attachment site and mantle were examined in recently set and older spat of *Crassostrea virginica*. Upon attaching the pediveliger stage secretes an adhesive from the pedal organ. This larval cement, a 2-8 μ thick layer interposed between the left valve and the substratum, is divisible into several fibrous zones based on transmission electron microscope examination. The main mass of cement is bounded externally and adjacent to the substratum is an outer zone of horizontal microfibrils. Above this zone is an inner one consisting of large fibers that project perpendicularly from, but never contact, the prodissococonch shell surface. Proximal to the shell are several alternating layers of electron dense and electron lucent bands of cement having a combined width of 25 nm.

After the initial attachment of the pediveliger at metamorphosis, the dissoconch shell begins to grow along the substratum. For the next two to three weeks, the mantle consists of two folds with a convoluted periostracum arising between them. Electron microscope examination reveals a trilayered periostracum, an electron lucent layer bounded by two electron dense layers, with a width of 30 nm. The periostracum maintains this layering after it has come to lie between the left valve and the substratum.

A modified silver methenamine technique was used for the electron staining of polyphenols. Positive results for polyphenols, and also tyrosine, suggest that the larval cement is a tanned protein. After metamorphosis, the polyphenol-rich periostracum attaches the advancing edge of the left valve to the substratum. Two additional features of the dissoconch mantle may also be playing a role in adhesion. Glycoproteins and polyphenols within a gland cell and among secretory droplets along the inner fold may contribute to forming the tanned periostracum.

PERMEABILITY OF THE SIPHUNCULAR TUBE OF *NAUTILUS* AND ITS RELATION TO BUOYANCY CONTROL.

William A. Moore

Department of Geology, Brooklyn College
Brooklyn, N.Y.

ABSTRACT

Siphuncular flow rates 30 to 80 times greater than observed in live *Nautilus*, and siphuncular permeability ranging from 8 to 28 microdarcys have been measured in freshly sectioned shells. The siphuncular tube bursts at pressures equivalent to 800 to 850 meters in depth. A slight increase in permeability flow rates in progressive camerae, with growth, provide the animal with the capability to empty or fill each chamber in approximately the same time span. My results support the 1980 work of Collins, Ward, & Westerman in that large scale vertical migration does

not occur by the buoyancy control mechanism. Using the siphuncular flow rates, measured in this experiment, an empty shell of a freshly killed animal will be prevented from reaching the surface if killed below ≈ 200 meters. This implies that post-mortem drift in shelled cephalopods may not be nearly as wide spread as previously believed.

MATING AND SPAWNING BEHAVIOR IN *EUPLEURA CAUDATA*
(SAY, 1922) (GASTROPODA: MURICIDAE)

Gregory L. Gruber

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ABSTRACT

Mating behavior is divided into two periods: propodial and tentacular activity, and copulation. During propodial and tentacular activity, the male, mounted on the right posterior side of the shell aperture of the female, touches her mantle edge with the front edge of his propodium and then with the tip of one of his tentacles. The male then forms a v-shaped groove with his propodium. During copulation, the male extends his penis through this groove into her vaginal aperture. Propodial and tentacular activity lasts several minutes; copulation lasts at least two hours and usually longer. The male may use propodial and tentacular touching for sex recognition or to stimulate the female for copulation. Spawning behavior is divided into four periods: propodial activity, egg capsule transport, ventral pedal gland activity, and egg capsule release. During propodial activity, the female licks the substratum one or more times with the anterior ventral edge of her propodium. During egg capsule transport, a deep groove temporarily forms on the right side of the propodium and carries an egg capsule from the pallial oviduct into the ventral pedal gland. Initially, the ventral pedal gland rotates the egg capsule, but this may not continue throughout ventral pedal gland activity. During egg capsule release, the propodium lifts vertically away from the substratum and releases the egg capsule from this gland; a propodial lick follows immediately. A female deposits one egg capsule for each cycle of these four periods. Propodial activity lasts about 45 minutes; egg capsule transport lasts about 5 minutes; ventral pedal gland activity lasts about 70 minutes; egg capsule release lasts about 10 minutes. The propodial licks during propodial activity and egg capsule release may aid adhesion of the egg capsule to a hard substratum. Egg capsule transport and ventral pedal gland activity properly shape, harden and attach the egg capsule to a hard substratum.

A PRELIMINARY OVERVIEW OF
THE SEGUENZIIDAE VERRILL, 1884

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ABSTRACT

A synthesis of the literature and my observations indicate that the Seguenziidae are modified gastropods of the order Archaeogastropoda. The family, as is here defined, comprises seven genera: *Seguenzia* Jeffreys, 1876; *Basilissa* Watson, 1879; *Ancistrobasis* Dall, 1889; *Basilissopsis* Dautzenberg & Fischer, 1897; *Guttula* Schepman, 1908; *Thelyssa* Bayer, 1971; and a genus encompassing *Fluxina discula* Dall, 1889. Characters of the family include: small, trochoid, nacreous shells with 0-3 labial sinuses; modified rhipidoglossate radula with rhachidian, single laterals, and reduced number of marginals; and paucispiral operculum. Approximately 70 species have been described to date, but perhaps only 50% to 70% of the total number has been recognized.

Some members of the fossil family Omphalotrochidae, particularly *Babylonites* Yochelson, 1956, are suggested as possible predecessors of the Seguenziidae.

SOME CHARACTERISTICS OF A SPRING INCURSION OF *APLYSIA*
INTO SHALLOW WATER IN SOUTH FLORIDA

Paul V. Hamilton

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Pensacola, Fla.

ABSTRACT

Two months of field observations indicate that springtime aggregations of *A. brasiliana* in shallow water are related to reproduction and that stranding on beaches is not storm-related. Daytime swimming in passes between islands was rare, regardless of tide. These data are related to a hypothesized annual migration.

ULTRASTRUCTURE OF THE BACTERIAL PHOTOPHORE OF
THE SEPIOLID SQUID *EUPRYMNA SCOLOPES*.

Carl T. Singley

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Iowa City, IO

ABSTRACT

Euprymna scolopes possesses a pair of bioluminescent photophores lying within the ventral-lateral surface of the ink sac. Each photophore consists of a pair of lobular transparent lenses and a sacculate crypt housing the symbiotic bioluminescent bacteria. Each crypt is connected with the mantle cavity by a ciliated canal which opens at the ventral-lateral surface of the ink sac. The fine structure of the photophore is described and the functional significance discussed.

NOTES ON THE FRESHWATER MOLLUSKS
OF CENTRAL AMERICA.

Arthur H. Clarke

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ABSTRACT

The molluscan faunas of Lago de Yojoa in Honduras and Gatun Lake in Panama were studied to provide bases for predicting the future faunas of artificial lakes in their vicinities. The results of this work, particularly with reference to schistosomus-vector snails, will be discussed.

NAIAD REDISTRIBUTION DUE TO FLOODING

Glenn A. Long

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ABSTRACT

Two examples, one from the Potomac River System and one from the Ohio River System, are presented to demonstrate clam redistribution due to flooding caused by a single severe storm.

FURTHER STUDIES ON THE EFFECTS OF ANTIFOULING
COATINGS ON MOLLUSCS AND OTHER ORGANISMS.

Dee S. Dundee

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ABSTRACT

Organotin antifoulants, widely used now on ships throughout the

world, are highly toxic, not only to fouling organisms, but to all others as well. Recent studies involve marine organisms (instead of estuarine organisms as in previous studies) including several molluscs.

THE REPRODUCTIVE CYCLE OF *LOLIGO PEALEI* LESUEUR, 1821.

William K. Macy III

Graduate School of Oceanography, University of Rhode Island
Narragansett, RI

ABSTRACT

Cluster and discriminant analyses were used to develop a system for classifying *Loligo pealei* by stages of sexual development using a few easily measured parameters. Using this system the annual reproductive cycle was documented in terms of population sexual development, gonad indices, and length-weight relationships.

WHAT DOES THE APERTURE TELL ABOUT THE SHAPE OF THE GASTROPOD SHELL?

Cato. Ten Hallers - Tjabbes

Dept. Zoology, University of Washington
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ABSTRACT

Early simulation models of gastropod shell growth did not vary aperture shape; recent biometric investigations have indicated its importance. By adding shell material along the aperture, the animal moulds the whorls of its shell. The effect of aperture shape on shell form is investigated by applying aperture dimensions in a geometric model of gastropod shell growth.

ANNOTATED BIBLIOGRAPHY OF THE MOLLUSCA OF KENTUCKY.

Walter E. Sage III

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ABSTRACT

This paper presents a discussion of the literature on the Mollusca of Kentucky, with emphasis on the publication that are most useful in identifying the land and freshwater forms.

NEW OCCURRENCES OF MOLLUSKS TO ABROLHOS IS., BAHIA

Eliezer de C. Rios and Lauro P. Barcellos

Museu Oceanografico da FURG
Rio Grande, RS. Brasil

ABSTRACT

In February, 1978, a group of researchers of Rio Grande Oceanographic Museum, under the leadership of the Junior Author, went Abrolhos Archipelago (17°57' x 39°42' W), 40 miles off the coast and collected a large number of mollusks. The results of this expedition will be published in the *Comunicaciones de la Sociedad Malacologica del Uruguay*.

In January, 1980, the same students returned to this Archipelago to resume their research to obtain a better knowledge of the Abrolhos malacofauna. The group stayed for 30 days on the largest island, Santa Barbara, and collected shells in tide pools, diving and dredging to 15 meters of depth.

The mollusks of Abrolhos are not completely known. In 1870 (Thayer Exp. Rept. 174-214) Hartt mentioned a few species. In 1961-62 the

"Calypso" dredged around the islands. The results of this work were published in "Resultats Scientifiques des Campagnes de la Calypso". In 1975, Rios reported 80 species (Brazil Mar. Moll. Iconography, Mus. Oceanog. de FURG, 1975). Petuch (Proc. Bio. Soc., Wash. 92(3): 510-526, 1979) described 10 new species and in our first study we mentioned 64 species. We list below 12 species not found in Abrolhos before. Those marked by * are new records for Brasil also.

Family FISSURELLIDAE

Puncturella pauper Dall, 1927 (*)

Family MATHILDIDAE

Mathilda sp. (*)

Family NATICIDAE

Natica menkeana (Philippi, 1852) (*)

Family TRIVIIDAE

Trivia antillarum Schilder, 1922

Family COLUMBELLIDAE

Aesopus steamsii Tryon, 1883 (*)

Family OLIVIDAE

Ancilla dimidiata (Sowerby, 1950)

Family MARGINELLIDAE

Marginella janeiroensis E.A. Smith, 1915

Granulina ovuliformis (Orbigny, 1841)

Family PYRAMIDELLIDAE

Odostomia aff. *aepynota* Dall & Bartsch, 1909 (*)

Fargoa bushiana Bartsch, 1909

Family CYLINDROBULLIDAE

Cylindrobulla beauui P. Fischer, 1856

Family SOLEMYIDAE

Solemya occidentalis Deshayes, 1857 (*)

THE CIRROMORPHA, A REVIEW OF THE FINNED OCTOPODS.

Gilbert L. Voss

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ABSTRACT

New collections of cirromorph cephalopods have permitted a re-evaluation of cirromorph biology, morphology and classification. Based upon characters of the internal shell, primary and secondary webs, web arrangement, gill structure, and body orientation, combined with information from deep-sea photographs, a new grouping of families, subgenera, and genera is suggested.

TAXONOMIC REVISIONS OF MARINE LYONSIIDAE (BIVALVIA)

Robert S. Prezant

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ABSTRACT

The segregation of molluscan taxa into generic groups is often obfuscated by the sole use of shell characteristics. This apportionment is most understandable from a palaeontological point of view but cannot be condoned for extant organisms. The lyonsiid bivalves offer a case in point. Using only shell characteristics, several taxonomists have previously divided the Lyonsiidae into as many as seven genera and at least as many subgenera or "sections". This has been especially true of the "*Entodesma*" group. Species within the latter taxon are often found nestled within tight, confining quarters where shell shape and texture may be molded to "fit" their micro-environments.

Based upon an holistic taxonomic approach, the Lyonsiidae are divisible into three distinct marine genera: *Lyonsia*, *Entodesma*, and *Mytilimeria*. Characteristics that readily separate these genera may be found in the gross morphology of the foot, byssus, mantle, adductor muscles, and siphons, and in umbonal length ratio differences. At the microscopic level the three are distinguishable by distinctions in shell ultrastructure and possession and structure of arenophilic mantle glands. Intergeneric habitat differences are also notable; *Lyonsia* are free-burrowers in fine sediments, species of *Entodesma* are nestlers within rocky crevices or among tunicates, sponges or coelenterates, and the monotypic *Mytilimeria nuttalli* is always found embedded within compound tunicates.

Evolution within the Lyonsiidae has centered around hypertrophy of the posterior adductor muscle, reduction of the pedal and byssal systems, modifications of the mantle and shell, variations in umbonal length ratios, and increasing sedentarianism. The Lyonsiids, as a group, offer a working model of a higher taxon that has relatively clear-cut taxonomic divisions among genera that also offer an identifiable phylogeny based upon distinct morphologies, ultrastructures, and life-styles.

FOOD OF A WEST INDIAN TURRID ASSEMBLAGE

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ABSTRACT

Eight species of five Turridae subfamilies inhabiting sand-drifted coral rock in shallow waters of Guana Island, British Virgin Islands, feed upon nine species of polychaetes and one sipunculid species. Four of the turrids prey upon more than one polychaete species. Two closely related members of the assemblage, *Pilsbryspira albomaculata* and *P. leucocyma*, prey upon carnivorous and deposit feeding worms respectively.

Assemblage of Turridae
Guana Island, British Virgin Islands

Strictispirinae

Strictispira paxillus (Reeve, 1845)

Clavinae

Drillia cydia (Bartsch, 1943)

Turriculinae

Pyrgospira candace (Dall, 1919)

Crassispirinae

Buchema interstrigata (E.A. Smith, 1882)

Crassispira (*Crassiclava*) *apicata* (Reeve, 1845)

C. (Monilispira) pellispinosa (Reeve, 1845)

Borsoniinae

Pilsbryspira albomaculata (Orbigny, 1842)

P. leucocyma (Dall, 1883)

THE CONE VALVE, OR PRIMARY EXCURRENT SIPHON OF HETERODONT BIVALVE MOLLUSCS AND THEIR CLOSE RELATIVES.

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ABSTRACT

In some heterodont bivalves there is a thin, transparent, conical valve around the excurrent siphonal opening of non-siphonate forms, or at the distal end of the excurrent tubular siphon when that is present. This distinctive organ is here termed the cone valve.

It is best studied in living animals, because details are difficult to determine in preserved specimens. It is relatively larger in species which are less than 25 mm maximum size. Of species which grow larger, the cone valve is prominent only in smaller specimens, diminishing and even disappearing in later growth stages. Correlated with the size of the individual, the form of the cone valve varies in approximate sequence from conoid to pear-shaped to spheroid to cylindrical to discoid. Its outer opening always lacks tentacles; its retraction and expansion can be very rapid, probably effected by slight opening and closing of the shell valves rather than by intrinsic musculature of the cone valve. When withdrawn, the cone valve inverts rather than contracts.

The absence of the cone valve in Protobranchia, Arcacea, Mytilacea, Pinnacea, Pteriomorpha and Paleoheterodontia indicate that this organ appeared in bivalve phylogeny after those groups were differentiated.

The cone valve is present in the lower heterodonts such as Crassatellidae and Astartidae; in some Lucinidae it is very long, but a posterior, tubular, incurrent siphon is absent. It may be the major excurrent siphon of some Psidiidae (Sphaeriidae); it is present in Corbulidae but absent in Leptonacea.

In higher heterodonts it is present in all families of the Veneracea and Myacea, but secondarily absent in all Tellinacea, thus lacking in all species which have a cruciform muscle.

In non-heterodonts it is present in some Adesmacea (Pholadidae but not Teredinidae), in some Anomalodesmacea and in the Septibranchia. Those groups were therefore derived from a heterodont stock after the phylogenetic appearance of this organ.

AN APLACOPHORAN MOLLUSK IN BRASILIAN WATERS

Eliezer de C. Rios

Museu Oceanografico de Rio Grande, RS, Brasil

ABSTRACT

In July, 1977, the research ship "Mestre Jeronimo" collected two specimens of *Neomenia herwigii* Kaiser, 1976, family Neomeniidae, order Neomenioidea, class Aplacophora at 117 meters off Chui, Rio Grande.

This mollusk is No. 20.704 in the Malacological Laboratory of Rio Grande Oceanographic Museum, RS, Brasil. This is the first record of an aplacophoran mollusk in Brasil.

Neomenia herwigii Kaiser, 1976

The Brazilian specimen is described: animal very large (200 x 56 mm.) cylindrical body (arched after preservation), with a ventral groove containing a narrow foot, light brown to grayish in color. A dorsocaudal sensitive organ placed above the cloaca hidden in a fold and another atrial sensitive organ near the mouth. Radula lacking. Anterior intestine trunklike; medium intestine with 100 transversal folds and at the sides of terminal intestine there are 50 gills. Cloacal orifice transverse, Median longitudinal groove (pedal groove) ending in a pedal pit. Sedentary and even motionless. Depth from 85 to 800 meters.

Geographical distribution of the species: Rio Grande do Sul to South Argentina and Falklands Islands.

THE NAIADES OF MISSOURI

Ronald D. Oesch

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ABSTRACT

Missouri's mussel population in the northern streams is gone and, while populations in the southern rivers are generally present, the effects of fertilizers, pesticides, sewage, deforestation and erosion are taking their toll. Only two statewide studies have been conducted in Missouri: William I. Utterback (1915-16) and the present one. Utterback concentrated in

the northern half of the state above the Missouri River, with less intensive work in the southern half. He listed 100 species and subspecies; the number reported today is 67 (representing 35 genera). Sixteen species that Utterback listed have not been found since. The remaining difference in numbers of species is due to the grouping together of his many subspecies.

Currently, the most significant assemblage of mussels is in the Mera-mec River basin with a total of 45 of the 67 species being found there. Prior to this study it was believed that no mussels inhabited the Mississippi River between St. Louis and its confluence with the Ohio River. However, the extreme low water level of the river in 1974 enabled me to find 17 species from three locations downstream from St. Louis. It is my belief that the decreased turbidity of the Missouri River plus sewerage control efforts are making this repopulation possible.

Also noteworthy at this time is the area in the southwest part of the state, where the Elk River, Shoal Creek, and the Spring River flow westward into Oklahoma and Kansas. Indigenous in these rivers are *Cyprogenia aberti*, already proposed for inclusion on the Federal List of Endangered Species; *Quadrula cylindrica cylindrica* listed as endangered in Missouri; and *Lampsilis rafinesqueana* whose total known national range is limited to probably no more than 100 miles of these three streams.

SYMPOSIUM: FUNCTIONAL MORPHOLOGY IN CEPHALOPODS

Rapporteur: William Hulet
Marine Biomedical Institute
University of Texas, Galveston, TX

This symposium is to be published in full in *Malacologia*.

THE FUNCTIONAL ORGANIZATION OF CHROMATOPHORES AND IRIDOPHORES IN THE BODY PATTERNING OF *LOLIGO PLEI* (CEPHALOPODA, MYOPSIDA).

Roger T. Hanlon

Marine Biomedical Institute, University of Texas Medical Branch
Galveston, TX

THE "KIDNEYS" OF CEPHALOPODS: A UNIQUE HABITAT FOR PARASITES.

F.G. Hochberg

Santa Barbara Museum of Natural History
Santa Barbara, CA

THE FUNCTIONAL MORPHOLOGY OF A PHOTOPHORE FROM A MESOPELAGIC SQUID.

R.E. Young and J.M. Arnold

University of Hawaii, Honolulu, HI

THE MORPHOLOGY OF THE POSTERIOR SALIVARY GLANDS OF *OCTOPUS DOFLEINI*.

Steven L. Brocco

Departments of Zoology and Oral Biology, University of Washington
Seattle, WA

HISTOCHEMISTRY AND FINE STRUCTURE OF THE ECTODERMAL EPITHELIUM OF THE SEPIOLID SQUID *EUPRYMNA SCOLOPES*.

Carl T. Singley

Department of Zoology, University of Iowa
Iowa City, IO

DEVELOPMENTAL ASPECTS OF THE MANTLE COMPLEX OF CEPHALOPODS.

S.V. Boletzky

C.N.R.S., Laboratoire Arago
Banyuls-sur-Mer, France

MORPHOLOGICAL AND PHYSIOLOGICAL UNITS OF CHROMATOPHORES: ARE THEY THE SAME?

A. Packard

Department of Physiology, University Medical School
Edinburgh, Scotland
(Read by Roger Hanlon)

SYMPOSIUM: FEEDING MECHANISMS OF PREDATORY MOLLUSKS

Rapporteur: Alan Kohn

COMPARATIVE MORPHOLOGY OF RADULAE AND MID-GUTS IN THE APLACOPHORA.

Amelie H. Scheltema

Woods Hole Oceanographic Institution
Woods Hole, MA

FEEDING METHODS OF THE CASSIDAE.

Roger N. Hughes

University College of North Wales
Bangor, U.K.

SHELL PENETRATION AND FEEDING BY NATICACEAN AND MURICACEAN PREDATORY GASTROPODS: A REVIEW

Melbourne R. Carriker

University of Delaware
Lewes, DE

EVOLUTION AND FUNCTIONING OF THE TOXOGLOSSAN FEEDING MECHANISM.

Ronald L. Shimek and Alan J. Kohn

Friday Harbor Laboratories, Friday Harbor, WA
University of Washington, Seattle, WA

FEEDING MECHANISMS OF NUDIBRANCHS WITH SPECIAL RESPECT TO THE RADULA.

James Nybakken

Moss Landing Marine Laboratory
Moss Landing, CA

THE ROLE OF GASTROPODS IN THE TROPHIC STRUCTURE OF FOSSIL COMMUNITIES.

¹Robert J. Stanton Jr., ¹Eric N. Powell and ²Penelope C. Nelson

¹Texas A&M University, College Station, TX

²Tulsa, Oklahoma

SESSION SUMMARY — Alan Kohn

AMU ANNUAL REPORTS

AMU ANNUAL BUSINESS MEETING

July 24, 1980

Louisville, Kentucky

President Clyde F.E. Roper called the annual business meeting of the American Malacological Union to order in the Label Room of Executive Inn, Louisville, Kentucky, at 3:30 p.m. on Thursday, July 24, 1980.

Minutes from the 1979 annual business meeting as printed in the 1979 Bulletin were approved.

Recording Secretary Constance E. Boone summarized 1979 membership, noting that for the second year in a row there had been an increase. Report approved. (Printed below in full).

Treasurer Myra L. Taylor summarized her report for fiscal year 1979. Approved. (Full report printed below).

A summary of Corresponding Secretary Paul Jennewein's activities for the year was given by the recording secretary. Approved. (Printed in full below).

The recording secretary summarized Editor Dee Dundee's report to Council on AMU publications, noting that the 1979 Bulletin had six more pages than the 1978 Bulletin and that there had been a change to smaller type in order to print more papers. All spaces on pages had been filled to cut costs. Total cost of the 1979 Bulletin was \$4,949.56. The two Newsletters cost \$789.78. The Editor said that present postage charges for overseas delivery is sufficient. If the rates go up, AMU charges for overseas delivery will be increased also, she noted. Report approved.

Dr. Roper announced that Council had approved holding the 1981 annual meeting at Ft. Lauderdale, Florida, July 19-25, and had approved holding the 1982 meeting in New Orleans, Louisiana. Approval was granted by the membership for both sites.

Dr. Richard S. Houbbrick, incoming president, discussed the 1981 meeting, pointing out that this 47th annual meeting actually would celebrate the fiftieth anniversary of the founding of AMU. Special events are planned on the history of AMU. Galt Ocean Mile Hotel has been selected for headquarters. Dr. Houbbrick noted that this hotel was close to shopping facilities and the beaches. A major symposium is planned on "Functional morphology and ontogeny of mollusca as applied to higher category systematics". A symposium on endangered mollusca and a refresher course on Paleozoic and Mesozoic mollusca are planned. Programs geared to amateurs, such as the ones held at Louisville, are scheduled also.

Dr. Roper explained that motions and requests from the conservation meeting held on Sunday during this annual meeting and delivered to Council would be handled by an executive committee on conservation headed by Dr. Carol Stein.

Dr. Roper announced that Archives Chairman William J. Clench had reported to Council that more materials were being added to the Archives housed at the Academy of Natural Sciences at Philadelphia. Dr. Clench has expressed the desire for pictures of individual AMU members for the archives.

Dr. Houbbrick presented the budget as approved by Council. The budget voted for 1981 follows:

INCOME

Memberships (all types except life members)	\$ 7,857.50
Sales	
HTSCS	300.00
Rare & Endangered Species Booklet	10.00
Bulletin, back issues	100.00
Teskey Index	50.00
	subtotal (\$ 460.00)
Page charges to authors	\$1,000.00
Proceeds of meeting	900.00
Donations, Symposium	100.00
Miscellaneous	40.00
	Total \$10,357.50
(Interest, Savings, not added to income, \$250.00)	

DISBURSEMENT

Bulletin	\$ 5,200.00
Newsletters	825.00
Conservation committee	50.00
Membership committee	25.00
President's organizing fund	500.00
California filing fee	5.00
Officers to meetings	1200.00
Legal defense	50.00
Postage (except Bulletin and Newsletters)	600.00
Printing (except Bulletin and Newsletters)	200.00
Office supplies	75.00
Postal permit	45.00
Miscellaneous	150.00
Council of Systematic Malacology	25.00
Annual meeting expense	150.00
Ads of meeting, HTSCS, etc.	500.00
Membership WSM	7.50
Symposia subsidies	500.00
Student prize, paper	250.00
	Total \$10,357.50

The Auditing Committee's report that the books were in order as signed by members of the committee was accepted.

The slate of officers selected by the nominating committee, headed by Dr. Joseph Rosewater, with assistance of Dr. Harald A. Rehder and Dr. Donald R. Moore, was read by the recording secretary. The officers elected are as follows:

President	Richard S. Houbbrick (One year term)
President Elect	Louise Russert Kraemer (One year term)
Vice President	Alan J. Kohn (One year term)
Corresponding Secretary	Paul R. Jennewein (Three year term)
Publications Editor	Dee S. Dundee (Five year term)
Councillors-At-Large	William G. Lyons (Two year term)
	John J. Jenkinson (Two year term)

Other officers include Constance E. Boone, Recording Secretary in second year of term; Myra L. Taylor, Treasurer, in third year of term;

Virginia Vail and Florence Kuczynski, Councilors-At-Large, in second year of term. H. Wallace Roberts continues as Legal Advisor.

Dr. Roper discussed a report to Council from the Council of Systematic Malacologists which had met on Sunday of this annual meeting. This included the information that Dr. Fred Thompson's study of mollusk collections would be completed and published and that Dr. Shi-Kuei Wu's survey of unused collections would be written up and published also.

A motion from Council recommended the publication in an AMU newsletter of the summary of the survey on courses on malacology prepared by Dr. Harold Murray for CSM. Approved.

Dr. Roper announced that he had asked Dr. Tucker Abbott to prepare a report on the feasibility of printing a pamphlet that AMU can distribute outlining career opportunities in malacology. Dr. Roper suggested that members interested in this project see Dr. Abbott.

Dr. Roper reported that Dr. David Stansbery, chairman of the Committee on Common Names of Mollusks, stated that the work on the list is continuing and that input from members in setting up principles to govern such a list is invited.

A motion brought from Council to send the AMU booklet, *How to Study and Collect Shells*, to all new members was approved.

A motion from Council to offer shell clubs and other organizations the opportunity to purchase 6 or more copies of HSCS at a fifty percent discount, plus postage, was approved.

Dr. Roper explained that the above motions were designed to get better distribution for this popular booklet and also offer an incentive to membership.

The symposia at this meeting were well received, according to Dr. Roper, and he stated that he felt that they were valuable program additions and good for AMU. He expressed his thanks to participants and to members who had expressed their enthusiasm for special events at this meeting.

Discussion on planned future symposia at Council had resulted in a motion modifying the original mandate for symposia. Members approved the motion stating that the wording of the original mandate to have world class symposia be changed to state that the president should be encouraged to organize symposia wherever possible within the constraints of the budget.

The announcement was made that this year's president has been charged by Council to seek the most desirable method of publication of this year's symposia papers.

A motion from Council was approved by members, authorizing President Roper to commit up to \$2,000 from AMU's general fund for the publication of the symposia of this meeting. Dr. Roper explained that this outlay of money was granted with the expectation of repayment.

A motion from Council that a book and shell auction be permitted at the 1981 meeting, with all proceeds to go to AMU, was approved. Dr. Houbbrick had stated that no endangered species would be sold.

By unanimous approval from Council, the petition-submitted by more than 10 members in good standing requesting that Henry van der Schalie and Morris K. Jacobson be nominated for honorary life members was submitted to the general membership and received immediate approval.

A call for new business brought the presentation of a resolution by Dr. Roger Hanlon concerning publication of a series on mollusca. Seconded and voted by members, the resolution is as follows: "Because the remaining volumes on Mollusca in the Libby Hyman series are recognized as being of major importance to the entire scientific community as well as to professional and amateur malacologists, be it resolved that the American Malacological Union recommend and encourage the publisher, McGraw-Hill, to resume preparation and publication of the following unwritten parts: Pelecypoda, Scaphapoda, Cephalopoda." Dr. Roper would comply with informing McGraw-Hill of AMU's action.

Newsletter Editor Dorothy Beetle explained changes to be made in the Newsletters. The two issues of each year will be given the same volume number, to coincide with the membership year. The Fall Newsletter from now on will report activities and officers of shell clubs; the Spring Newsletter will report research activities of professional members and institutions.

A discussion was held concerning the possibility of printing the program or the titles of papers early enough to be distributed to members to encourage more attendance at the meetings and to inform members concerning symposia and special events. The problems of getting this done early enough for mailing and the cost factors were discussed. No action was taken.

A motion was approved to send greetings to the honorary life president and the honorary life members not present at this meeting.

Adjournment came at 4:34 p.m.

Respectfully submitted,

Constance E. Boone
Recording Secretary

REPORT OF THE TREASURER FOR THE FISCAL YEAR ENDING DECEMBER 31, 1979

CHECK BOOK BALANCE, JANUARY 1, 1979

\$ 3,601.89

RECEIPTS:

Memberships	
Regular	4,447.00
Life	175.00
Sustaining	67.00
Corresponding	251.50

Clubs & Institutions, Domestic	879.50		
Clubs & Institutions, Foreign	286.00		
Subscriptions	<u>75.00</u>	6,181.00	
Sales:			
HOW TO STUDY & COLLECT SHELLS	158.50		
RARE & ENDANGERED SPECIES	8.75		
TESKEY INDEX TO BULLETINS	54.00		
BULLETIN, Back Issues	<u>116.50</u>	337.75	
Page Charges to Authors	952.50		
Miscellaneous Donations	36.00		
Symposia Fund Donations	560.00		
North Carolina Meeting Proceeds	1,382.91		
Corpus Christi Meeting Proceeds	1,529.83		
Miscellaneous receipts	<u>8.00</u>		
		<u>4,469.24</u>	
Total Receipts From All Activities		<u>10,987.99</u>	<u>10,987.99</u>
TOTAL CASH ACCOUNTED FOR:			14,589.88
DISBURSEMENTS:			
BULLETIN, Printing, Postage, etc.	3,466.15		
NEWSLETTER, Printing, Postage, etc.	649.27		
Conservation Committee	10.37		
President Old's Expenses	163.74		
President Roper's Expenses	9.14		
California Filing Fee	5.00		
Officers' Expenses to meeting	677.51		
Other postage	508.53		
Other Printing	149.09		
Council of Systematic Dues, 1979 & 1980	50.00		
WSM Student Award Fund	100.00		
SCIENCE Advertisement	192.00		
OF SEA & SHORE Advertisement	300.00		
Bank Charges & Refunds	27.50		
Miscellaneous	611.07		
Transfer to Life Membership CD.	<u>175.00</u>		
		<u>7,094.37</u>	
Total Disbursements from all Activities			<u>\$ 7,094.37</u>
CHECK BOOK BALANCE ON DECEMBER 31, 1979		\$ 7,495.51	
TOTAL CASH ACCOUNTED FOR:			14,589.88
SASA* Savings Account #5-034514	4,468.28**		
Interest Added	<u>246.74</u>		
Total For Account		4,715.02	
SASA* Savings Certificate #5-904812 (Life Membership Fund)	2,427.37		
Interest Added	166.66		
Life Membership Added	<u>175.00</u>		
Total For Account		<u>2,768.81</u>	
TOTAL SAVINGS		7,483.83	

*SASA = San Antonio Savings Association

**Inadvertently, the Treasurer, the Auditors and Council Members failed to note an error in the 1977 Treasurer's Report, in which the amount of \$1,510.58 was subtracted twice, leaving a balance then incorrect. This error is now corrected, and the 1979 Auditors satisfied.

RECAPITULATION OF ASSETS, DECEMBER 31, 1979:

Cash in Checking Account, Mercantile Bank	7,495.51
Treasurer's Petty Cash	20.00
Secretary's Petty Cash	175.00
SASA* Account #5-034514	4,715.02
TOTAL ASSETS	12,405.53
LIFE MEMBERSHIP SAVINGS CERTIFICATE #5-904812	2,768.81
AMU NET WORTH, DECEMBER 31, 1979	12,405.53
CHANGES IN CAPITAL ACCOUNT:	
AMU Capital Account, January 1, 1979	8,220.17
AMU Capital Account, December 31, 1979	12,405.53
NET INCREASE IN ASSETS IN 1979	4,185.36

Respectfully submitted,
Myra L. Taylor, Treasurer

REPORT FROM THE RECORDING SECRETARY

Minutes from the Annual Membership Meeting held during the Forty-Fifth Annual Meeting at Corpus Christi last August were printed in the 1979 AMU Bulletin.

A substantial increase in membership is noted happily for the fiscal year of 1979. This seems to be due equally to the increased number of new members and the lower number of members dropped for nonpayment of dues.

The account of membership for 1979 is as follows:

Honorary Life President	1
Honorary Life Members	8
Regular Members (Western Hemisphere)	518
Additional Family Members	83
Foreign Corresponding Members	15
Affiliated Members (Institutions, etc.)	52
Clubs, regional org., corporations	35
Life Members	28
Total	740
Subscription to Bulletin only	8

The total membership figure for 1978 was 708. Therefore, we show a gain of 32 members for 1979, most being regular members.

By July 1, 1980 we had enrolled 81 new and reinstated members for 1980. Many of the symposia speakers for this year's meeting became members. We secured new and reinstated members because of the efforts of Dr. Harold Harry acting as chairman of a committee for the

AMU Council of Systematic malacologists seeking information from professionals on courses being taught on malacology. Dr. Harry included our application in his questionnaire. He plans in the future to prepare a list of authors of papers on malacology who are not now members of AMU so that we may send them membership letters.

However, a note of caution must be given at this time. This is the first year of the raise in dues. As of July 1, 1980, we had 187 members (from all categories) who had not paid 1980 dues. This is not unusual for midyear, but we do need to follow up and secure dues from present members in order to maintain our gain in overall membership this year also.

The usual business of this office has continued—welcoming letters to new members, letters answering inquiries concerning publications, mailing of orders of Bulletins, Index, Symposium on Rare and Endangered Mollusks, preparing materials for the Editor of the AMU Bulletin, remailing returned Newsletters and Bulletins, etc.

Expenses of this office for 1979 were higher as predicted last year. Postage continues its spiral climb upwards, and printing costs are more always. New membership letters were printed, and mailing tabs are provided for all AMU mailings. Cost of running all business for 1979 was \$356.38.

Respectfully submitted,

Constance E. Boone

FROM THE CORRESPONDING SECRETARY

During 1979, mail from Europe began increasing. Apparently, the dollar's relative value declined in comparison with the foreign currencies and prompted Europeans to write, seeking information on malacology. Most of the letters, however, were related to saltwater specimens and collections. Mail from Spain, along with requests for "How to Study and

Collect Shells" seemed much higher than in previous years.

Mail is still being received through Mrs. Marian S. Hubbard, former secretary, who has been forwarding it. Because of her expense, I sent her a book of stamps to encourage her to forward the letters.

Sold were 75 books, which brought a total of \$186.25. (As the AMU charges postage for commercial accounts, there's an odd figure.) Expenses came to \$148.79, of which postage was \$123.98, reflecting the increase in foreign mail and postage required to send replies.

Respectfully submitted,

Paul R. Jennewein

THE AMERICAN MALACOLOGICAL UNION, INC.

Active Members 1980

(Membership List Revised October 15, 1980)

Abbott, Dr. R. Tucker, P.O. Box 2255, Melbourne, FL. 32901.
 Adler, Dr. Howard, 116 Edgewood Drive, Bridgewater, N.J. 08807
 (Marine-radiography).
 Aguayo, Dr. Carlos G., Dept. of Biology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708.
 Ahlstedt, Steven, 11 East Norris Road, Norris, TN. 37828 (Biological aide in Fisheries management, TVA).
 Albert, Mrs. Ernest, 905 S. Bayshore Blvd., Safety Harbor, FL. 33572.
 Alexander, Robert C., 423 Warwick Rd., Wynnewood, PA. 19096.
 Allen, James E., 1108 Southampton Dr., Alexandria, LA. 71301
 (Tertiary micro-mollusca).
 Allen, Dr. J. Frances, 7507 23rd Ave., Hyattsville, MD. 20783
 Allen, Mrs. Lawrence K. (Betty), Box 822, Port Isabel, TX. 78578
 (*Murex*, *Pecten*, world marines; owner, Shop of the Seven Seas).
 Allen, Miss Letha S., 187 Argyle St. Yarmouth, Nova Scotia, Canada B5A 3X2 (General).
 Amarantunga, Tissa, Dept. Fisheries and Oceans, Resource Branch, Box 550, Halifax, Nova Scotia, B3J 2S7. Canada (Life history, biology and management of Cephalopods).
 Anders, Kirk W., Shells of the Sea, Inc., P.O. Box 1418, Ft. Lauderdale, FL. 33302 (Volutidae, all rare shells).
 Anderson, Carleton Jay Jr., 56 Kettle Creek Rd., Weston, CT. 06883.
 Andrews, Dr. Jean, 241 Melrose, Corpus Christi, TX. 78404.
 Arrington, Mr. and Mrs. Stewart F. Jr., 15932 Brewster Rd., Cleveland, OH. 44112 (Shells with postage stamps and worldwide marine).
 Ashwell, James R., P.O. Box 555, Windermere, FL., 32786 (General).
 Athearn, Herbert D., Museum of Fluvial Mollusks, Rt. 5, Box 499, Cleveland, TN. 37311 (Freshwater mollusks).
 Athearn, Mrs. Roy C., 5105 N. Main St., Fall River, MA. 02720 (Land shells).
 Avellanet, Mrs. Helene, 105 Clipper Way, Fair Winds Villas, Nokomis, FL. 33555.
 Avery, Mrs. R. Gail, Box 2557, Harbor, OR. 97415 (West American mollusks; exchange).
 Aviles E., Prof. Miguel C., Apartado 6-765, Zona Postal El Dorado, Panama, Rep. of Panama (Histology and Embryology).
 Babrakzai, Mr. Noorullah, Dept. General Biology, Univ. of Arizona, Tucson, AZ. 85721.
 Baerreis, David A., 1233 Sweet Briar Rd., Madison, WI. 53705
 (Paleoecological interpretation through mollusks).
 Bailey, Dr. Joshua L. Jr., 4435 Ampudia St., San Diego, CA. 92103.
 Baker, Mrs. Horace B., 11 Chelton Rd., Havertown, PA. 19083.
 Baker, Sam, Candi, Jeffrey and Ryan, 1530 Astec Circle, Naperville, IL. 60540 (Collecting cones and cowries).
 Bargar, Tom and Denise Schneider-Bargar, 320 S. Beltline Blvd., Apt. 31-D, Columbia, S.C. 29205 (Functional morphology of gastropods).
 Barlow, Mrs. G. Barton, 76 Westervelt Ave., Tenafly, N.J. 07670.
 Barr, John W., Jr., 312 Windward Dr., League City, TX. 77573
 (*Cypraeidae*).
 Bates, Dr. John M., 1900 Dexter Ave., Ann Arbor, MI. 48103.

Bauer, Laura M., 2126 45th St., Galveston, TX. 77550 (All mollusks).
 Baum, Newman N., 83 Weaving Lane, Wantagh, L.I., N.Y., 11793.
 Bazata, Kenneth R., Hazelton Environmental Sciences, 4010 NW 39th St., Bldg. 1374, Lincoln, NB. 68524 (Terrestrial pulmonates; *Dentalium*).
 Beetle, Ms. Dorothy E., director, Patterson Planetarium, 2900 Floyd Road, Columbus, GA. 31907 (U.S. land and fresh water mollusks).
 Bequaert, Dr. Joseph C., 24 Berkshire Terrace, Amherst, MA. 01002.
 Bergmann, Joseph A., Rt. 3, Box 3064, Boerne, TX. 78006 (Land and freshwater mollusks, recent and fossil).
 Berke, Ian, 4032 23rd St., San Francisco, CA. 94114.
 Berry Dr. Elmer G., 8506 Beech Tree Court, Bethesda, MD. 20034.
 Berry, Dr. S. Stillman, 1145 W. Highland Ave., Redlands, CA. 92373.
 Bianchi, Mrs. Ann, Box 235, Goodland, FL. 33933.
 Biasca, Mrs. Cynthia, 5811 Cheena, Houston, TX. 77096.
 Bickel, David, 613 W. Ave. C, Bismarck, N.D. 58501 (Systematics and ecology of freshwater mollusks, esp. Pleurocerid snails).
 Bijur, Jerome M. 135 Seventh Ave. N., Naples, FL. 33940 (Buy, exchange Florida, Caribbean and Gulf of Mexico marine).
 Bippus, Emma Leah, 2743 Sagamore Rd., Toledo, Ohio, 43606 (Marine gastropods).
 Bishop, David, Dept. of Marine Science, 830 First Street South, St. Petersburg, FL. 33701.
 Bishop, Thomas Dale, Dept. of Biology, Univ. of Southwestern Louisiana, Lafayette, LA. 70504 (Ecology related to gastropods).
 Blaisten, Dr. Lia O.B. de, Laboratorios Bioquímex, S.A. de C.V., Nicolas San Juan 1535, Colonia del Valle, Mexico 12, Mexico (Scientist amateur—American and Caribbean seashells; cowries and *Strombus*).
 Bleakney, Dr. J. Sherman, Dept. of Biology, Acadia Univ., Wolfville, Nova Scotia, Canada BOP 1X0 Nudibranchs and sacoglossans; ecology, zoogeography, systematics).
 Bledsoe, William D., 352 Bon Hill Rd., Los Angeles, CA. 90049.
 Body, Ralph L., 2538 10th Ave. W., Seattle, WA. 98119. (Taxonomy).
 Bogan, Arthur E., Research Ass't. Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916.
 Boone, Mr. and Mrs. Hollis Q., 3706 Rice Blvd., Houston, TX. 77005.
 Boss, Dr. Kenneth M., Museum of Comparative Zoology, Harvard, Univ., Cambridge, MA. 02138.
 Bottimer, L.J., Rt. 1, Box 205, Tow, TX. 78672 (recent and fossil mollusks).
 Bowers, Raymond E. and Sylvia G., 128 E. Oakland Ave., Columbus, OH. 43201 (Freshwater ecology of Naiades).
 Boyd, Dr. and Mrs. Eugene S., 6806 Gillis rd., Victor, N.Y. 14564 (All aspects of Phylum Mollusca).
 Brakonietz, Thomas F., RSMAS, 4600 Rickenbacker Causeway, Miami, FL. 33149 (*Cephalopoda*).
 Brandauer, Mrs. Nancy E., 1760 Sunset Blvd., Boulder, CO. 80302.
 Branson, Dr. Branley A., P.O. 50, Eastern Kentucky Univ., Richmond, KY. 40475.
 Bratcher, Mrs. Twila, 8121 Mulholland Terrace, Hollywood, CA. 90046.
 Brice, James R., 310 N. Prairie, Mundelein, IL. 60060.
 Britton, Dr. Joseph C., Dept. of Biology, Texas Christian Univ., Ft. Worth, TX. 76129.

- Brocco, Dr. Steven Louis, 4404 52nd NE., Seattle, WA. 98105 (Cephalopod biology).
- Brooks, Jane M., 3050 Sunrise Blvd., Ft. Pierce, FL. 33450.
- Brown, Drs. Harvey and Marjorie, 9455 S.W. 81st Ave., Miami, FL., 33156.
- Broyles, Mrs. Ralph E., 5701 Fairfield Ave., Ft. Wayne, IN. 46807.
- Brunson, Dr. Royal Bruce, 1522 34th St., Missoula, MT. 59801.
- Buchanan, Alan, Missouri Dept. of Conservation, Fish & Wildlife Research Ctr., 1110 College Ave., Columbia, MO. 65201 (Fisheries biologist).
- Buckley, George D., 164 Renfrew St., Arlington, MA 02174.
- Burch, Dr. John B., Malacological Review, P.O. Box 420, Whitmore Lake, MI. 48189 (Land and fresh water mollusks).
- Burch, Mrs. John Q., 1300 Mayfield Rd., Apt. 61-L, Seal Beach, CA. 90740.
- Burch, Dr. Tom and Beatrice L., P.O. Box 309, Kailua, Hawaii 96734. (BLB, planktonic mollusks; TAB, deepwater mollusks).
- Burgess, Charles, 8902 Tolman Road, Richmond, VA. 23229 (Volutes, worldwide).
- Burger, Sybil B., 3700 Gen. Patch N.E., Albuquerque, NM 87111 (Gulf of Mexico; land snails).
- Burke, Mrs. Patricia, 18128 Lakeside Lane, Nassau Bay, TX 77058.
- Burky, Dr. Albert J., Dept. of Biology, Univ. of Dayton, Dayton, OH. 45469.
- Caldwell, Dr. Ronald S., 407 Broadway, Frankfort, KY. 40601 (Terrestrial gastropods of Kentucky).
- Call, Sam M., 107 Goodrich Ave., Lexington, KY. 40503 (Pelecypods).
- Calnan, Thomas R., Univ. of Texas Bureau of Economic Geology, University Station Box X, Austin, TX. 78712 (Gulf Coast mollusks).
- Campbell, Mrs. Minnie Lee and Donald C., 3894 DuPont Circle, Jacksonville, FL., 32205 (General).
- Capo, Thomas R., 59 Nickerson St., Falmouth, MA. 02540 (Benthic Ecology).
- Cardeza, R. Adm. and Mrs. Carlos M. Dec. to Mar. 29, P.O. Box 6746, Houston, TX. 77005; April 1 to Nov. 30, 1718 Jewel Box Dr., Sanibel, FL. 33957 (Florida and Texas shells).
- Cardin, Charles, 12571 S.W. 268 St., Naranja, FL. 33032 (Ovulidae, registered shell dealer).
- Carlton, James T., Woods Hole Oceanographic Institution, Woods Hole, MA., 02543 (estuarine and brackish water mollusks.).
- Camey, Dr. W. Patrick, Box 2, NAMRU 2, Jakarta, APO San Francisco, CA. 96356.
- Cariker, Prof. Melbourne R., College of Marine Studies, Lewes Complex, Univ. of Delaware, Lewes, DE. 19958.
- Carroll, Susan E., 32-03 150 St., Flushing, N.Y. 11354 (Parasitology in marine mollusks).
- Carson, John and Laura W., 221 Elm Ave., Morrisville, PA. 19067.
- Castagna, Michael, Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Pelecypod larval behavior).
- Cate, Mr. and Mrs. Crawford N., P.O. Drawer 710, Rancho Santa Fe, CA. 92067 (*Mitra*, *Cypraea*; no exchanges).
- Cetnar, Dr. and Mrs. Eugene J., 4379 Ramsgate Lane, W. Bloomfield, MI. 48013.
- Chadwick, Albert F., 2607 Turner Rd., Wilmington, DE. 19803 (Marine shells).
- Chambers, Dr. Steven, Office of Endangered Species, U.S. Fish and Wildlife Service, Dept. of the Interior, Washington, DC 20240.
- Chanley, Paul and Mattie, P.O. Box 12, Grant, FL. 32949.
- Chappell, Mrs. Elaine, 2435 Dunloe Drive, Dallas, TX. 75228 (All mollusks).
- Charbonneau, Roger, 100 East Prieur St., Montreal, Canada H3L 1C9.
- Chichester, Lyle F., Dept. Biol. Sciences, Central Conn. State College, 31 Chamberlain St., New Britain, CT. 06052 (Ecology of terrestrial gastropods, biology of land slugs).
- Christensen, Carl C., 1612 Kamole St., Honolulu, HI. 96821.
- Christie, Dr. John D., Dept. of Pathology, Univ. of Texas Medical Branch, Galveston, TX. 77550.
- Chrosiecowski, Przemyslaw K., APTDO 125, Maracay, Venezuela, 3KO (Planorbidae).
- Chung, Daniel, Div. of Mollusks, Ruthven Museum, Univ. of Michigan, Ann Arbor, MI. 48109 (Pulmonates; Hawaiian mollusks).
- Clark, Miss Violette W., 1706 Lincoln Rd., Champaign, IL. 61820 June through October; 9790 66th St. N., Box 310, Pinellas Park, FL. 33565 Nov. through May.
- Clarke, Dr. Arthur H., Dept. of Mollusks, USNM, Smithsonian, NHB-E 514, Washington, D.C. 20560.
- Clench, Dr. William J., 26 Rowena St., Dorchester, MA. 02124.
- Clover, Philip W., P.O. Box 83, Glen Ellen, CA. 95442 (Rare *Cypraea*, *Conus*, *Voluta*, *Murex*, *Marginella* – Buy and exchange).
- Clymer, George M., MN. Dept. of Natural Resources, Ecological Services Section, Box 25, 628 Cedar St., St. Paul, MN. 55155.
- Coan, Dr. Eugene V., 891 San Jude Ave., Palo Alto, CA. 94306.
- Cole, Timothy James, Hom Point Environmental Laboratory, Univ. of Maryland, Box 775, Cambridge, MD. 21613 (Genetic divergence among molluscan populations; ecological-genetic interdigitations).
- Coleman, Dr. Richard W., Dept. of Biology, Prof. of Science and Head, Upper Iowa University, Fayette, IA. 52142 (Environmental Inter-relationships, plants-invertebrates).
- Colmenares, Raul Peraza, Lra transversal de Sebulan, Quinta "Don Raul", Caracas, Venezuela, 107 (Taxonomy and effects of pollutants on mollusks).
- Compitello, Mrs. Juliette, 5630 Alta Vista Rd., Bethesda, MD 20034.
- Conde, Vincent, McGill University (Redpath Museum), Montreal Canada H1O.
- Coney, Cliff, 2008 Canterbury Rd., Kingsport, TN. 37660 (Grad student at East Tenn. State Univ., investigating niche partitioning by the terrestrial mollusca of the Ridge and Valley Province of southeastern Tenn.).
- Cook, Dr. Susan B., Dept. of Zoology, The Ohio State University, 1735 Neil Ave., Columbus, OH. 43210 (Behavioral ecology of tropical marine gastropods; behavioral ecology of freshwater gastropods).
- Cooper, Robert W., 5012 Pfeiffer Rd., Peoria, IL. 61607 (Florida marine; *Murex*, *Pecten*, *Spondylus*, *SCUBA*).
- Conklin, William A., R.T. (FASRT): President, Inner Dimension, 1571 Marshall Ave., Orangeburg, S.C. 29115 (Radiography/photography).
- Corgan, Dr. James X., Dept. of Geology, Austin Peay Univ., Clarksville, TN. 37040 (*Pyramidellidae*, *Vitrinellidae*, *Scaphopods*, *Tentariy faunas*).
- Comely, Guy, 53 rue Jean-Jaures Raizet, Abymes, Guadeloupe, French West Indies.
- Cosman, Dieter, 7 Oak Hill Rd., Huntington, NY. 11743 (Marine tropical and subtropical Gastropoda and Bivalvia worldwide).
- Counts, Clement L., III, College of Marine Studies, University of Delaware, Lewes, DE. 19958 (Zoogeography, taxonomy).
- Courtney, Charles M., director, MAMES, 900 N. Barfield Dr., Marco Island, FL. 33937 (Aquatic ecology/malacology).
- Covey, Philip A. and Jewell M., Aptdo 547, Guaymas, Sonora, Mexico (Panamic Province, all mollusks, and *Epitoniacea*, worldwide).
- Craine, Mrs. Ruth A., P.O. Box 2001, Southern Pines, NC 28387.
- Cramer, Frances L., 766 Obispo Ave., Long Beach, CA 90804 (Ecology; conservation).
- Crissinger, Myrna May and William (Bill), 820 North Court Street, Crown Point, IN. 46307.
- Croft, Mrs. Thomas L., 9393 Ladue Rd., St. Louis, MO. 63124 (Marine; fossils).
- Cull, Alice J., 7927 Chippewa Rd., Brecksville, OH. 44141.
- Cummings, George P., Jr., 815 Cedar Oak Lane, Harker Heights, TX. 76541 (Taxonomy, speciation, intraspecific variation).
- Cummings, Raymond W., 37 Lynacres Blvd., Fayetteville, NY. 13066 (West Indies shells, esp. Windward and Grenadine Is.).
- Cutler, Henry H., 105 Abbott Rd., Wellesley Hills, MA. 02181.
- Cvancara, Dr. Alan Milton, Dept. Geology, Univ. of N. Dakota, Grand Forks, ND. 58202 (Pleistocene and Holocene continental mollusks, early Tertiary continental and marine).
- Danforth, Louise L., 2529 Terry Lane, Sarasota, FL. 33581.
- Darcy, George H., Univ. of Miami Sch. of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Davenport, Mrs. Lillian B., 802 Cape Ave., Box 81, Cape May Point, NJ. 08212 (Conchology, malacology, pertaining to the sea).

- Davis, Dr. Derek S., Nova Scotia museum, 1747 Summer St., Halifax, NS, B3M 3A6 Canada (Gastropod biology and taxonomy).
- Davis, Dr. George M., Academy of Natural Sciences of Philadelphia, 19th and the Parkway, Philadelphia, PA. 19103.
- Davis, Dr. John D., 25 Old Homestead Rd., P.O. Box 156, Westford, MA. 01886 (Ecology of marine bivalves).
- Davis, The Venerable Robert N., 1309 Hedgelawn Way, Raleigh, N.C. 27609 (To help promote the survival of systematic mollusk collections and institutions).
- Deatrick, Paul A., 218 S.W. 32 Ave., Miami, FL. 33135 (Strombus, Busycon).
- de Graaff, Gerrit, 10915 S.W. 55 St., Miami, FL. 33165.
- Deisler, J.E., Zoology Dept., Univ. of Florida, Gainesville, FL. 32611. (Systematics of tropical land snails).
- DeLuca, Mrs. Theresa and Ms. Gladys DeLuca, 61 Deborah Rd., Hanover, MA. 02339.
- Demond, Miss Joan, 202 Bicknell Ave., #8 Santa Monica, CA. 90405.
- Dexter, Miss Norma, 150 Barker Hill Dr., RFD 3, Guildford, CT. 06437 (Cypraea).
- Dexter, Dr. Ralph W., Dept. Biological Science, Kent State Univ., Kent, OH. 44242.
- Deynzer, Albert E. and Beverly A., Showcase Shells, 1614 Periwinkle Way, Sanibel, FL. 33957 (Marine mollusks).
- Dietrich, Mr. and Mrs. Louis E., 308 Veri Dr., Pittsburgh, PA. 15220.
- Dilley, Donald R., Rm. 304, 1220 N. Street, Dept. of Food and Agriculture, State of Calif., Sacramento, CA. 95814 (Mollusks of economic importance to agriculture).
- Dillon, Robert T., Jr., 155 B. Wilson Rd., Maple Shade, N.J. 08052.
- Dolin, Eric, 107 Briar Brae Rd., Stamford, CT. 06903 (Conus, Cypraeidae, Strombus, Voluta).
- Doyle, Miss Patricia, 336 Pine Ave., St. Lambert, Quebec, Canada J4P 2N8.
- Draper, Bertram C., 8511 Blierot, Los Angeles, CA. 90045 (Eastern Pacific minute mollusks and all Western U.S. marine).
- DuBar, Jules R. and Susan S., Rt. 1, Box 70, Morehead, KY. 40351 (Cenozoic and recent mollusks—ecology and paleoecology).
- Dugdale, H.K., P.O. Box 1392, Wilmington, DE. 19899 (Editor, Chambered Nautilus Newsletter).
- Dundee, Dr. Dee S., Dept. of Biology, Univ. of New Orleans, Lakefront, New Orleans, LA. 70122 (Land mollusks, freshwater mussels).
- Dvorak, Stanley J., 3856 W. 26th St., Chicago, IL. 60623 (Muricidae).
- Eddison, Grace G., M.D., "Wildwood," Rt. 4, Carlisle, KY. 40311.
- Edwards, D. Craig, Dept. of Zoology, Morrill Science Center, Univ. of Massachusetts, Amherst, MA. 01003 (Population ecology and behavior of marine benthic mollusks).
- Elwell, Dr. Adela, Rt. 2, Box 268, Bemidji, MN. 56601 (Terrestrial gastropods).
- Elwell, Mrs. Marden F., 4 Crestview Dr., Cherry Hill, N.J. 08003.
- Emberton, Kenneth C., Committee on Evolutionary Biology, Univ. of Chicago, Chicago, IL. 60637 (Land snails).
- Emerson, Dr. William K., American Museum of Natural History, Central Park West at 79th St., New York, NY. 10024.
- English, Rita C. and James F., 10300 Terrace Court, Parma, OH. 44130 (Fossils: Florida and Caribbean; ecology of mangrove areas).
- Enright-Huff, Mr. Dan and Ms. Peggy, 1601 Eastcrest Drive, Apt. #L-2, Charlotte, N.C. 28205 (scallops, tun, whelk, conch).
- Erickson, Carl W., 4 Windsor Ave., Auburn, MA. 01501.
- Eubanks, Dr. Elizabeth R., 57 Lyall St., West Roxbury, MA. 02132 (Florida marine shells).
- Evans, Roger, 1900 Camino de la Costa, Apt. 1, Redondo Beach, CA. 90277 (Diver; marine mollusks of Southern California).
- Evans, Miss Susan E., 244 Congress Ave., Lansdowne, PA. 19050 (Conus, Cypraea, Murex).
- Eversole, Dr. Arnold G., Ass't. Prof., Dept. of Economic Zoology, Clemson Univ., Clemson, SC. 29631. (Interpopulation variation and bioenergetics of molluscan populations).
- Everson, Gene D., 5224 Northwest 17th Court, Lauderhill, FL. 33313 (Worldwide collection with emphasis on Florida, Caribbean and miniatures).
- Fairbanks, Dr. H. Lee, Penn State University, Beaver Campus, Brodhead Road, Monaca, PA. 15061 (Systematics of land gastropods; genetic variability of land gastropods).
- Feber, Olive M., 4777 Sandia, Los Alamos, N.M. 87544 (Cones and cowries).
- Fechtner, Frederick R., 2611 W. Fitch Ave., Chicago, IL. 60645.
- Feinberg, Harold S., Dept. of Fossil and Living Invertebrates, American Museum of Nat. Hist., Central Park West at 79th St., N.Y., NY. 10024 (Polygyridae and other U.S. Pulmonata).
- Ferguson, Dr. and Mrs. John H., 226 Glandon Dr., Chapel Hill, NC. 27514.
- Fieberg, Mrs. Kleinie, 1430 Lake Ave., Wilmette, IL. 60091.
- Fields, Mrs. Esther L., 1706 Lincoln Rd., Champaign, IL. 61820, June through October; 9790 66th St. North, Pinellas Park, FL. 33565, Box 310, November through May.
- Finlay, C. John, 116 Tanglewood Lane, Newark, DE. 19711 (Marine mollusks Western Atlantic and Caribbean).
- Foehrenbach, Jack, 91 Elm St., Islip Manor, NY. 11751 (Marine ecology).
- Fontanier, Dr. Charles E., P.O. Box 6201, Waco, TX. 76706 (Ecology, Unionids of Lake Brazos, Waco, TX.; Cypraeidae; SCUBA).
- Foot, Miss Mary K., Apt. 418, 7201 Spencer Hwy., Pasadena, TX. 77505 (Land snails and self-collected miniatures of the Texas coast).
- Foster, Mrs. Fred H., 401 N. Justus St., Oxford, IN. 47971.
- Fowden, (Mrs.) Jeanne B., 444-54 Whispering Pines Dr., Scotts Valley, CA. 95066 (Limpets; sand dollars).
- Franzen, Dr. Dorothea, Science Programs, Illinois Wesleyan Univ., Bloomington, IL. 61701.
- Freitag, Thomas M., 13602 137th Ave. West, Taylor Ridge, IL. 61284 (Freshwater mussels, especially endangered species; freshwater and terrestrial gastropods).
- Frye, Mark W., 3521 Liv-Moor Dr., Columbus, OH. 43227 (Naiads, Micropaleontology with specialty in Ordovician micro-mollusks).
- Fuess, Thomas and Mary Fuess, 6978 Pickadilly Ct. SW, Ft. Myers, FL., 33907 (Southwest Florida coast and Florida Keys mollusks).
- Fullington, Richard W. and Kate E., 3013 Rosedale Ave., Dallas, TX. 75205 (Land and freshwater gastropods of North America, esp. SW N.A.; curator, invert. zoology, Dallas Museum of Natural History).
- Furbish, Dean R., 1977 Cambridge Dr., Apt. 1, Lexington, KY. 40504 (Behavior, physiology of mollusks).
- Gallindo, Lic. Ernesto Santos, Jorge Elliot #12, Colonia Polanco, 70 piso, Mexico, D.F.5.
- Garcia, Dr. Emilio Fabian, 115 Oak Crest Dr., Lafayette, LA. 70503 (Gulf of Mexico and Caribbean mollusks).
- Gardner, L.D. (Lu), 2425 N. Bartlett, Milwaukee, WI. 53211.
- Gardner, Mrs. Sandra M., 1755 Univ. Ave., Palo Alto, CA. 94301 (Vermetidae).
- Geller, Mrs. Leonard, 336 DeMott Ave., Rockville Centre, NY. 11570.
- Gerberich, Andrew G., 5029 South 23rd St., Arlington, VA. 22206 (Fresh water mussels).
- Gerhold, Robert M., senior microbiologist, Nalco Chemical Co., 1801 Diehl Rd., Naperville, IL. 60540 (Environmental physiology and mollusk pest control).
- Germer, John and Dorothy, 653 Briarcliff Ave., Maywood, NJ. 07607 (John: photography of shells; Dorothy: Pectens and Murex and shells of the Eastern and Western Atlantic).
- Germon, Mrs. Raye N., 27 Rosemont Dr., Gaithersburg, MD. 20760 (Muricidae, Volutidae, Mesozoic and Paleozoic fossils marine).
- Gibbons, Ms. Mary C., Marine Sciences Research Center, State Univ. of New York, Stony Brook, N.Y. 11794.
- Gilbert, Dr. William H., Dept. Biology, Simpson College, Indianola, IO. 50125 (Marine and freshwater bivalves — ecology, behavior, systematics; *Tellina*, *Macoma*).
- Gill, Richard W., Wapora, Inc., 4348 Riverline Drive, Earth City, MO. 63045 (Riverine Pelecypoda).
- Gilmour, Dr. Thomas H.J., Dept. Biology, Univ. of Saskatchewan, Saskatoon, Sask., Canada S7N 0W0 (Ansimoyarian bivalves).
- Girardi, Dr. Elizabeth-Louise, 707 Kent Rd., Kenilworth, IL. 60043.
- Goethel, Lt. Col. (Ret.) and Mrs. Louis N., 9402 Nona Kay Dr., San Antonio, TX. 78217 (Cypraea — buy and trade).

- Gold, Albert, 118 W. 227 St., Bronx, NY. 10463.
- Goldberg, Richard L., 49-77 Fresh Meadow Lane, Flushing, NY. 11365 (Worldwide marine and land shells — collector and dealer — Hawaiian Achatinella tree snails).
- Golden, Myrna, 690 Hungry Harbor Rd., North Woodmere, N.Y. 11581 (Marine).
- Golightly, Charles Grady Jr. and Nancy Hamill, 1505 Lemon Tree Lane, College Station, TX. 77840 (Bivalve ecology/systematics).
- Goodfriend, Glenn A., Zoology Dept., Univ. of Florida, Gainesville, FL. 32611 (Molluscan ecology).
- Gooch, Charles H., Rt. 2, Box 498, Killen, AL. 35645.
- Gordon, Mackenzie Jr., Paleontology and Stratigraphy Branch, U.S. Geological Survey, Smithsonian, Washington, D.C. 20560.
- Gordon, Mark E., Dept. of Zoology, Univ. of Arkansas, Fayetteville AR. 72701 (Freshwater mollusks, Arkansas and mollusks of the Ozarks).
- Greenberg, Bayle, c/o Tidepool Gallery, 3907 W. 50th St., Edina, MN. 55424.
- Greenberg, Mrs. Janis, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greenberg, Mrs. Ruth, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greer, W.J., 13635 Butterfly Lane, Houston, TX. 77079 (Western Pacific and Australian Great Barrier Reef mollusks).
- Gruber, Gregory L., College of Marine Studies, University of Delaware, Lewes, DE. 19958 (Reproduction, Physiology).
- Guckert, Richard H., 1757 Kimberly Dr., Marietta, GA. 30060 (Systematics of freshwater mussels; ecology; physiology of Nassariidae).
- Gudnason, Kay, 105 Danefield Place, Moraga, CA. 94556.
- Gugler, Dr. Carl W., School of Life Sciences, U. of Neb., Lincoln, NB. 68588 (Terrestrial pulmonates).
- Gunter, Dr. Gordon, Gulf Coast Research Lab., Ocean Springs, MS. 39564 (Ostreidae).
- Hagge, Mrs. Daniel, 20 North Hill Rd., Wausau, WI. 54401.
- Haigh, Ernest S. and Marilyn E. and son, David, 6533 Orangewood Ave., Cypress, CA. 90630 (Worldwide seashells; trading and seashell stamps).
- Hall, Eleanor R., 1230 N.E. 88th St., Seattle, WA. 98115 (Marine gastropods, esp. worldwide Cypraea).
- Hall, Mrs. Warner L., 727 Queen's Rd., Charlotte, NC. 28207 (Self-collection, marine).
- Hamilton, Dr. Paul V., Dept. of Biology, Univ. of W. Florida, Pensacola, FL. 32504 (Behavior and ecology of gastropods).
- Hamilton, Ms. Suzanne, 631 Blossom, Rockville, MD. 20850 (Freshwater gastropods).
- Hamilton, William E., 13568 Magnolia Ave., Corona, CA. 91720 (Pacific Coast, N.A., esp. Southern Calif. to a depth of 110 ft. (Scuba). Favorite areas of study being the islands—Catalina, etc.).
- Hamilton, Mrs. William J. Jr., 615 Highland Rd., Ithaca, NY. 14850.
- Hand, Dr. Cadet H., Bodega Marine Lab, P.O. Box 247 Bodega Bay, CA. 94923.
- Hanley, John H., Branch of Paleontology and Stratigraphy, U.S. Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center, Denver, CO. 80225 (Taxonomy, paleoecology, biostratigraphy, and evolution of Mesozoic and Cenozoic nonmarine Mollusca).
- Hanlon, Dr. Roger T., UTMB-MBI, League Hall, R2, 200 University Blvd., Galveston, TX. 77550 (Cephalopod culture and behavior).
- Hansen, William P., 315 West 102 St., N.Y., NY. 10025.
- Hargreave, Dr. David, Ass't. Prof. Nat. Scs., College of Gen. Studies, Western Mich. Univ., 1104 Berkshire Dr., Kalamazoo, MI. 49007 (Collecting and photography).
- Harman, Dr. Willard N., Biology, State Univ. College at Oneonta, Oneonta, NY. 13825 (Fresh water mollusca).
- Harris, Ms. Bessie B.K., 28 Sylvan Ave., Wallingford, CT. 06492.
- Harris, Don V. Jr., 2803 P St. NW, Washington, D.C. 20007.
- Harris, Mr. & Mrs. E. Milton, 3237 Carlisle Rd., Birmingham, AL. 35213.
- Harry, Dr. Harold W. and Dr. Mildred, 4612 Evergreen St., Bellaire, TX. 77401.
- Hartenstine, Raymond H., Biologist, 965 Belvoir Rd., Norristown, PA 19401 (Fresh water malacology).
- Hartman, Joseph H., Dept. Geology/Geophysics, Univ. of Minn., 108 Pillsbury Hall, Minneapolis, MN. 55455 (Cretaceous-Eocene F.W. moll. of W. U.S.; Viviparidae).
- Hausser, Penny H., 127 Godfrey Lane, Huntington, NY. 11743.
- Haven, Dr. Dexter S., 336 Lafayette Rd., Yorktown, VA. 23690 (*Mercenaria mercenaria*, *Mya arenaria*, *Crassostrea virginica*).
- Havlik, Mrs. Marian E., 1603 Mississippi St., LaCrosse, WI. 54601 (Naiads of Miss. River).
- Hazin, Hissa Mussa, R. Dr. Isaac Salazar, No. 114, Tamarineira, Recife, Brazil (Basilian marine and foreign marine, conchological books).
- Helms, Don R., Aquatic biologist, RR#3, Box 63, Bellevue, IO. 52031 (Special interest in Mississippi River).
- Hepler, Neil M. and Laura E., 435 S. Federal Highway, Deerfield Beach, FL. 33441 (*Nautilus* and other *Cephalopods*).
- Herly, Paul W. and Margaret, RD#1, Box 224, Swainton, N.J. 08210 (Paul: Fossil; Peg: Cypraea).
- Hershler, Robert, Dept. of Earth and Planetary Science, The Johns Hopkins Univ., Baltimore, MD. 21218 (Ecology and anatomy of hydrobiid snails).
- Hess, Steven C., RSMAS/BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (*Cephalopod* biology and systematics).
- Hesterman, Caryl A., Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (North American Unionacea).
- Hettick, Mrs. G. Riley, 933 Lynnwood Dr., Bartlesville, OK. 74003.
- Hickey, Ms. Mary T., 4415 Independence St., Rockville, MD. 20853 (Scallops).
- Hickman, Dr. Carole S., Dept. of Paleontology, Univ. of Calif., Berkeley, CA. 94720 (tertiary molluscan paleontology).
- Hickman, Mrs. Harriette L., 20 Wilkie Blvd., Beesley's Point, Marmora, NJ. 08223 (Worldwide Epitonium).
- Hickok, George H., 27 Whitney Circle, Windsor, CT. 06095 (amateur).
- Hicks, Mr. and Mrs. Edwin S., 1522 Palmwood Dr., Eau Gallie, FL. 32935 (Recent and fossil marine shells of Western Atlantic).
- Higbee, Ms. Florence and Dr. Joan Higbee, 13 North Bedford St., Arlington, VA. 22201.
- Hillman, Robert D. Ph.D., Battelle-Clapp Laboratories, Duxbury, MA. 02332 (Molluscan ecology and physiology).
- Hixon, Raymond F., UTMB-MBI, League Hall, R2, Galveston, TX. 77550 (Cephalopods).
- Hoagland, Dr. K. Elaine, Dept. of Biology, Lehigh Univ., Bethlehem, PA. 18015.
- Hohman, Betty Jean, 10 Feris, Apt. 101, Highland Park, MI. 48203 (cones, Volutes, Murices).
- Holiman, Mr. and Mrs. Wayne, Box 246, Edinburgh, TX. 78539.
- Holle, Dr. Paul A., 131 Holman St., Shrewsbury MA. 01545 (Salt marsh snails).
- Hollister, S.C., 5 Parkway Place, Ithaca, NY. 14850.
- Homan, Mrs. Jacqueline A., N. Halpin Rd., Rt. 5, Box 230, Harlingen, TX. 78550.
- Hopkins, Dr. Sewell H., Rt. 3, Box 232, Gloucester, VA. 23061.
- Horan, Robert C., 352 20th St., Brooklyn, NY. 11215 (Biochemistry of shell formation).
- Horn, Karen J., Univ. of North Carolina Inst. of Marine Sciences, 3407 Arendell St., Morehead City, N.C. 28557 (Freshwater mollusks).
- Hornbach, Daniel J., Dept. of Biology, Univ. of Virginia, Charlottesville, VA. 22901 (Sphaeriid bivalves).
- Houbrick, Dr. Richard S., Assoc. Curator of Mollusks, Dept. of Invert. Zoology, NHB, E518, Smithsonian Institution, Washington, D.C. 20560 (Zoogeography, systematics, evolution).
- Houp, Katy and Ronald E., 519 N. Lexington Ave., Wilmore, KY. 40390 (Freshwater pelecypods).
- Hubbard, Mrs. Marian S., 3957 Marlow Court, Seaford, NY. 11783 (Littorinidae; all juvenile mollusks).
- Hubricht, Leslie, 4026 35th St., Meridian, MS. 39301 (Land snails and Hydrobiidae of Eastern United States).
- Hucks, Claudia M., 8120 Greenridge Rd., North Charleston, S.C. 29405 (East Coast marine, miniatures, microshells).
- Huie, Ms. June, 222 Finland, Grand Prairie, TX. 75050 (All mollusks).
- Hulswit, Maria and Tina, 680 West End Ave., New York, N.Y. 10025 (Scuba).

- Hyett, Dr. and Mrs. Marvin R., 403 Silverhill Rd., Cherry Hill, NJ. 08002.
- Imlay, Dr. Marc J. and Alice, Columbia National Fisheries Laboratory, Rt. 1, Columbia, MO. 65201.
- Ing, Michael B., Wildwood Sanitarium and Hospital, Wildwood, GA. 30757.
- Ishikawa, Samuel, 551 Fifth Ave., New York, NY. 10017.
- Isom, Billy G., Rt. 3, Box 444, Killen, AL. 35645.
- Jacobson, Mrs. Ursula, 5618 E. Montecito, Phoenix, AZ. 85018 (Indo-Pacific, esp. cones and cowries; West Coast-Panamic).
- Jagger, Mr. and Mrs. James M., RFD #1, Huntington, MA. 01050 (*Tellina*).
- James, Mrs. Frederic, 850 West 42nd St., Kansas City, MO. 64112.
- Jenkinson, John J., 909 Eagle Bend Rd., Clinton, TN. 37716 (Malacologist with TVA).
- Jennewein, Paul R. and Virginia N., Box 394, Wrightsville, Beach, NC. 28480 (Raising mollusks in aquaria; writing and illustrating articles on shell collecting).
- Joffe, Ms. Anne, c/o She Sells Sea Shells, 1983 Periwinkle, Sanibel Is., FL. 33957.
- Johns, Veronica Parker, c/o Seashells Unlimited, Inc., 590 Third Ave., New York, NY. 10016.
- Johnson, Barbara Lee, 1615 Yew Street, Mississauga, Ontario, Canada L5H 2C1 (Beginner, likes cowries, *Murex*, esp.).
- Johnson (Way), Elizabeth, Box 83, Topsail, C.B.S., Newfoundland, Canada A0A 3Y0 (Cephalopod blood cells hemopoiesis).
- Johnson, Col. Harvey A. (Ret.) 3915 S.W. 109th St., Seattle, WA. 98146.
- Johnson, Johnnie, 1635 Oceana Dr., Merritt Island, FL. 32952 (Curator, natural sciences, Brevard Museum, Inc.).
- Johnson, Mrs. Kenneth L., 3206 Sussex Rd., Raleigh, NC. 27607 (World marine).
- Johnson, Richard I., 124 Chestnut Hill Rd., Chestnut Hill, MA. 02167 (Books).
- Johnstone, Mrs. Adelaide B., 226 Wasp, Corpus Christi, TX. 78412.
- Johnstone, Mrs. Kathleen Yerger, 2209 River Forest Rd., Mobile, AL. 36605.
- Jokinen, Eileen, c/o Peter Rich, U-42, Biological Sciences Group, Univ. of Connecticut, Storrs, CT. 06268 (Freshwater gastropods).
- Jones, Margaret C. and Archie L., 4370 S.W. 14 St., Miami, FL. 33134 (*Liguus*).
- Jones, Meredith L., Division of Invert. Zoology, USNM, Smithsonian Institution, Washington, D.C. 20560.
- Jones, Richard H., 1432 Dorsh Rd., South Euclid, OH. 44121.
- Jones, Sue, Box 373, Rio Hondo, TX. 78583.
- Josey, Mrs. John S., 222 Devonwood Dr., St. Simons Is., GA. 31522 (Worldwide: self-collected, exchange; Japanese shells and fossils of GA. and FL.; professional artist, marine shells and marine paintings, teaches art at Brunswick Junior College).
- Kasson, Bill and Susan M., OSU Museum of Zoology, 1813 N. High St., Columbus, OH. 43210 (Distribution, diversity and systematics).
- Kat, Pieter W., Dept. Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD. 21218 (Unionidae).
- Kay, Dr. E. Alison, General Science Dept., Univ. of Hawaii, 2450 Campus Rd., Honolulu, HI. 96822 (Indo-Pacific marine mollusca: systematics and ecology).
- Keegan, Mrs. Barbara, 54 Franklin St., Franklin, NH. 03235.
- Keeler, Dr. James H., 30 Park Lane, Chagrin Falls, OH. 44022 (Marine, esp. micro Gastropods — Epitoniidae and Terebridae).
- Keen, Dr. A. Myra, 2241 Hanover St., Palo Alto, CA. 94306.
- Kefer, Dr. Eugene P., Div. of Nat. Sciences, Brunswick Junior College, Brunswick, GA. 31520 (Terrestrial gastropods).
- Kellogg, Michael G., Moss Landing Marine Laboratories, P.O. Box 223, Moss Landing, CA. 95039.
- Kemper, Mrs. HESSIE, 11854 Josse Dr., St. Louis, MO. 63128.
- Kenk, Dr. Vida, 18596 Paseo Pueblo, Saratoga, CA. 95070.
- Kennish, Michael J., Jersey Central Power and Light Co., Madison Ave. at Punch Bowl Rd., Morristown, N.J. 07960 (Shell microstructure in mollusks).
- Kier, William M., Dept. of Zoology, Duke University, Durham, N.C. 27706 (*Cephalopod* functional morphology).
- King, Gary and Debbra, Official Orders F/2/3, 1916 Berkeley Drive, Azle, TX. 76020.
- King, Lucia E., Heron Club, 434 Broad Ave. South, Naples, FL. 33940.
- Kinsey, Bernard, 350 W. 71st, New York, N.Y. 10023 (Land shells: also worldwide marine shells).
- Kitchel, Helen Elise, 968 N. State Rd., 149, Valparaiso, IN. 46383 (Laboratory of Limnology, Dept. of Zoology, Univ. of Wisconsin).
- Kline, Mrs. George F., 240 Makee Rd., Apt. 10-A, Honolulu, HI. 96815.
- Koelsch, Kip W., 26 Oakwood Rd., Leonardo, N.J. 07737 (*Cypraea*, *Cassis* and Atlantic *Nassarius*).
- Kohn, Dr. Alan J., Dept. Zoology, Univ. of Washington, Seattle, WA. 98195.
- Kokai, Mr. and Mrs. Frank L., 3472 Green Meadows St., Columbus, OH. 43207.
- Kondo, Dr. Yoshio, 809 A. Isenberg St., Honolulu, HI. 96826.
- Kool, Silvard, 410 Kingston Rd., Myrtle Beach, S.C. 29577 (Marine/ mollusks and freshwater mollusks of Eastern U.S.).
- Kotrla, M. Bowie, 607-26 Dixie Drive, Tallahassee, FL. 32304 (Parasites of snails).
- Kraczkowski, Mrs. Patricia N., 28 Bowen Briggs Ave., Warwick, R.I. 02886 (Shells of Rhode Island, particularly of Narragansett Bay).
- Kraemer, Dr. Louise Russert and Dr. William D., Dept. of Zoology, Univ. of Arkansas, Fayetteville, AK. 72701 (Freshwater lamellibranchs).
- Kraeuter, Dr. John N., Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Ecology, distribution and systematics of Scaphopoda; benthic infaunal communities of U.S. East Coast).
- Krafcheck, James R., 18375 W. Willow Dr., New Berlin, WI. 53151 (Collecting, general).
- Krauss, N.L.H., 2437 Parker Place, Honolulu, HI. 96822 (Carnivorous land snails; biology).
- Kuczynski, Mrs. Florence, 5562 2nd Ave. N., St. Petersburg, FL. 33710 (Collect, exchange, photograph all shells).
- Kurz, Richard M., 1575 N. 118 St. Wauwatosa, WI. 53226 (Specimen shells).
- Kuzirian, Dr. Alan M., Laboratory of Biophysics, NINCDS, Nat. Inst. of Health, Dept. of Health, Education, and Welfare at the Marine Biological Lab., Woods Hole, MA. 02543 (Nudibranch biology, systematics and taxonomy—phylogeny and morphology).
- Laavy, T.L., Rt. 5, Maruca Dr., Greenville, SC. 29609.
- Lamberts, Dr. Austin, 1520 Leffingwell, N.E., Grand Rapids, MI. 49505 (Coral reefs and associated mollusks).
- Landye, James Jerry, 3465 N. Jamison, Flagstaff, AZ. 86001.
- Lane, Dr. Roger L., Ashabula Campus, Kent State Univ., Ashtabula, OH. 44004 (Morphology, Histology).
- Lange, W. Harry, Dept. of Entomology, Univ. of California Davis, CA. 95616.
- Laursen, Dr. Dan, 4901 East Eastland, Tucson, AZ. 85711 (Arctic, Sub-arctic mollusks; Free living larvae of Caribbean and Gulf areas).
- Lee, Dr. Harry G., 709 Lomax St., Jacksonville, FL. 32204 (American mollusks; marine mollusks of the Indian Ocean).
- Leffert, Joseph S., 4000 NE 169 St., North Miami Beach, FL. 33160.
- Lemire, Ross, 184 Grandview Ave., Thornhill, Ont., Canada L3T 1J1.
- Leonard, Dr. A. Byron, 562 Snow Hall, Univ. of Kansas, Lawrence, KS. 66045 (late Cenozoic mollusca).
- Lerner, Martin, 64 Thompson Ave., Oceanside, NY. 11572 (Worldwide marine).
- Leslie, Dr. F. John, Dept. Biological Sciences, Stanford Univ., Stanford, CA. 94305 (*Haliotis*).
- Levy, Mrs. Esther W., 21 Lee Road, Sharon, MA. 02067.
- Lewis, Harold, 104 S. Twentieth St., Philadelphia, PA. 19103.
- Lewis, Mrs. J. Kenneth (Olive), 3340 Windmill Village #185-0, Punta Gorda, FL. 33950.
- Lewis, Dr. and Mrs. John R., 23 W. 551 Warrenville Rd., Lisle, IL. 60532.
- Lewis, Randall B., 210 Chandler Dr., Mundelein, IL. 60060.
- Lewis, Ronald G. and Susan, 1301 Mickley Rd., Apt. E-4, Whitehall, PA. 18052 (Marine Gastropoda, particularly Cypraeidae).

- Lillico, Stuart, 4300 Waialae Ave., B-1205, Honolulu, HI. 96816 (General collecting).
- Lindberg, David R., Applied Sciences, Univ. of California, Santa Cruz, CA. 95064.
- Linsley, Dr. Robert M., 111 East Lake Rd., Hamilton, N.Y. 13346 (Paleozoic Gastropoda).
- Lipford, Michael L., 2017 Airline Blvd., Portsmouth, VA. 23701 (Freshwater mussels).
- Logan, Robert W., 145 Northwood, Frankfort, KY. 40601 (Freshwater mussels and snails).
- Logue, Maureen, P.O. Box 3293, Damariscotta, ME. 04543 (Molluscan pathology and aquaculture).
- Long, Dr. Glenn A., 409 Sheridan Circle, Charlestown, W.VA. 25314 (Ethnoconchology).
- Lopinot, A.C., 45 Northcrest, Litchfield, IL. 62056 (Aquatic biologist, taxonomy and life history of freshwater mussels).
- Lowry, Walter G., 552 Old Lundy Rd., Macon, GA. 31210 (Western Atlantic).
- Lubinsky, Dr. Irene, 32 Thatcher Drive, Winnipeg, Man., Canada R3T 2L2 (Marine bivalves of the Canadian Arctic).
- Lupold, Hugh and Linda S., Box 396, Holly Hill, S.C. 29059 (S.C. coasts and Sanibel, FL.).
- Lustgarten, Linda, 44 Righters Mill Road, Gladwyn, PA. 19035 (Bahamas).
- Lutz, Richard A., Dept. of Geology and Geophysics, Yale Univ., New Haven, CT. 06520 (Bivalve shell structure and mineralogy; molluscan aquaculture; bivalve larval ecology).
- Lyons, Miss Sarah, 81 Lakeview Ave., N.E. Atlanta, GA. 30305.
- Lyons, William G., Florida Dept. of Natural Resources, Marine Lab, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Florida and West Indian mollusks).
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- MacKenzie, Roger Anthony, Lot 12, Morrie Coco Rd., Westmoorings, Trinidad, West Indies (Strombidae).
- Mackie, Dr. Gerry L., Dept. of Zoology, Univ. of Guelph, Guelph, Ont. Canada N1G 2W1 (Sphaeriids).
- MacMillan, Gordon K., 169 Glenfield Dr., Pittsburgh, PA. 15235.
- MacMillan, Thomas C., P.O. Belle Rivier, Wood Islands, PEI COA 2JO, Canada.
- Macy, William K. III, 146 Main St., North Kingstown, R.I. 02852 (Cephalopods).
- Maes, Virginia Orr, Dept. of Mollusks, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103.
- Magee, Mrs. Virginia L., Life Science Dept., Mitchell College, New London, CT. 06382 (New England mollusks, both living and Pleistocene).
- Malek, Dr. Emile, Tulane Univ. Medical School, 1430 Tulane Ave., New Orleans, LA. 70112 (Parasitology).
- Malone, Elsie, 2422 Periwinkle Way, P.O. Box 54, Sanibel Is., FL. 33957 (buy — sell — exchange world shells).
- Mann, Julia, Data Research Associates, 257 Park Ave. South, New York, N.Y. 10010.
- Marshall, Dr. Donald S., 2842 Ashby Ave., Berkeley, CA. 94705.
- Marshall, Elsie J. (Mrs. Thomas H.), 2237 N.E. 175th St., Seattle, WA. 98155 (World shells; exch.).
- Marti, Mrs. Ann P., P.O. Box 7, Trinity, AL. 35673 (Panamic marine shells and worldwide Murex).
- Martins, Antonio M., Frias, Dept. of Zoology, Univ. of Rhode Island, Kingston, RI. 02881.
- Mastenbroek, Paul W., 117 Church St., Woodbridge, Ontario, Canada L4L 1K9 (Distribution and systematics, Northern North Atlantic Ocean and adjacent seas).
- Mather, Dr. Charles M., Ass't. Prof. of Biology, Box 3457, University of Science and Arts of Oklahoma, Chickasha, OK. 73018 (Systematics and ecology of terrestrial molluscs and freshwater mussels).
- Mathiak, Harold A. and Julie, 209 S. Finch St., Horicon, WI. 53032 (Natural history of Wisconsin clams and recent species distribution; effects of fish toxicants on clams).
- May, Miss L. Helen, 8110 Ketcham Rd., South, Bloomington, IND. 47401 (N.A. seashells, emphasis on continental U.S.A.).
- Mayers, Dan, 648 Wiltshire Dr., State College, PA. 16801 (Taxonomy and life histories of mollusks).
- Mayo, Beryl Ivy and Franklin, 319 Narcissus Rd., Rt. 1, Kemah, TX. 77565 (Gulf shallow water and drift mollusks).
- Mazurkiewicz, Dr. Michael, Dept. of Biological Sciences, Univ. of Southern Maine, 96 Falmouth St., Portland, ME. 04103 (Larval development and ecology of estuarine mollusks).
- McCaleb, John E., Rt. 1, Box 54-A, Ashland, AL. 36251 (Freshwater mollusks of N.A., esp. Pleuroceridae).
- McCallum, John and Gladys, 4960 Gulf of Mexico Dr., Apt. PH6, Longboat Key, FL. 33548.
- McCarthy, Col. William A., 424 Hunting Lodge Dr., Miami Springs, FL. 33166.
- McCrary, Dr. Anne B., 411 Summer Rest Rd., Wilmington, NC. 28403.
- McGee, Paul L. and Helen, 10211 Bessemer, Houston, TX. 77034.
- McGhee, Mrs. Sandra L., 8401 W. Sample Road, #14, Coral Springs, FL. 33065 (Currently doing a research project on Patellidae, Acmaeidae and Lepetidae).
- McGinty, Thomas L., Box 765, Boynton Beach, FL. 33435.
- McHugh, Mrs. John, 4654 Quarry Ridge, Rockford, IL. 61103 (Murex).
- McInnes, Mrs. Cornelia G., F-6 Raleigh Apts., Raleigh, NC. 27605 (All Marine).
- McLean, Dr. James H., Los Angeles County Museum, 900 Exposition Blvd., Los Angeles, CA. 90007.
- McLeod, Dr. Michael J., Biology Dept., Belmont Abbey College, Belmont, NC. 28012 (Systematics and evolution).
- McRae, Mrs. Catherine, 1984 Roseate Lane, Sanibel Is., FL. 33957.
- Mead, Albert R., Associate Dean, Liberal Arts College, 347 Modern Languages Bldg., Univ. of Arizona, Tucson, AZ. 85721.
- Menzel, Dr. R.W., Dept. Oceanography, Florida State Univ., Tallahassee, FL. 32306 (Marine clams and oysters—biology).
- Merrill, Arthur and Harriet, 103 W. 8th Ave., Summerland Key, FL. 33042.
- Metcalf, Dr. Artie L., Dept. of Biological Sciences, Univ. of Texas at El Paso, El Paso, TX. 79968 (Terrestrial Gastropoda of S.W. U.S.).
- Metz, George, 121 Wild Horse Valley Drive, Novato, CA. 94947 (Chitons).
- Meyer, Harvey G., P.O. Box 61, Captiva, FL. 33924.
- Michaelson, Eliot, The Shell Gallery, Piccadilly Sq., 77 Union St., Newton Centre, MA. 02159.
- Michelson, Dr. Edward H., 44 Bishop Drive, Framingham, MA. 01701 (Medical malacology).
- Mikkelsen, Paul and Paula, 5011-B Sanibel Ave., Ft. Pierce, FL. 33450 (Paul—Donacidae; Paula—Tellinidae and Littorinidae).
- Miles, Dr. Charles D., Dept. of Biology, Univ. of Missouri—Kansas City, Kansas City, MO. 64110.
- Miller, Barry B., Dept. of Geology, Kent State Univ., Kent, OH. 44242 (Non-marine Pleistocene, Malacology).
- Miller, Dr. Walter B., 6140 Cerrada El Ocote, Tucson, AZ. 85718.
- Miser, Wendel L., 1108 Alden Rd., Alexandria, VA. 22308 (Fresh water mollusks).
- Moller, Gertrude H., 2248 University Blvd. South, Jacksonville, FL. 32216.
- Moore, Dr. and Mrs. Donald R., Rosensteel School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Moore, Eric and Eileen, P.O. Box 6606, Orange, CA. 92667.
- Morrison, Dr. J.P.E., 1330 4th St. S.W., Washington, D.C. 20024.
- Morrison, Robert W., P.O. Box 15011, Sarasota, FL. 33579 (Marine shells, esp. Cypraea, Voluta, Oliva and Murex).
- Morse, Dr. M. Patricia, Marine Science Institute, Northeastern University, Nahant, MA. 01908 (Interstitial molluscs—opisthobranchs and solengasters; Opisthobranchia).
- Mousley, Louis B., 35350 Panorama Dr., Yucaipa, CA. 92399.
- Murray, Mrs. Francis A., 3741 N.E. 24th Ave., Lighthouse Point, FL. 33064.
- Murray, Dr. Harold D., Biology Dept., Trinity Univ., San Antonio, TX. 78284 (Unionidae; distribution and parasites).
- Murray, Talbot, Graduate Sch. of Oceanography, Univ. of Rhode Island, Narragansett, RI. 02882.

- Myer, Dr. Donal G., Dept. of Biological Science, Southern Illinois Univ. at Edwardsville, IL. 62025 (Land snails).
- Naide, Dr. Meyer, 2034 Spruce St., Philadelphia, PA. 19103.
- Neck, Dr. Raymond W., Texas Parks and Wildlife Dept., 4200 Smith School Rd., Austin, TX. 78744 (Ecology, evolution and biogeography of nonmarine Mollusca).
- Neville, Bruce D., 1328 E. Marion Ave., Punta Gorda, FL. 33950 (Mangrove mollusks/systematics and ecology).
- Nicol, Dr. David, P.O. Box 14376, University Station, Gainesville, FL. 32604.
- Nilson, Joy S., Rt. 5, Box 3156, Bonita Springs, FL. 33923 (Mollusks of New England and Florida).
- Noseworthy, Ronald G., P.O. Box 104, 41 Main St., Grand Bank, Newfoundland, Canada A0E 1W0 (North Am. circumboreal mollusks; also Clausiliidae and Turridae).
- Notter, Miss Helen, 1115 S. Edgewood Ave., Apt. 608, Jacksonville, FL. 32205.
- Nunley, Rodney E., Univ. of Houston Marine Science Program, 4700 Ave. U, Bldg. 305, Galveston, TX. 77550 (Ecology and distribution of tropical and subtropical marine molluscs).
- Nunnally, Mrs. Sally and Douglas G., 512 N. Channel Drive, Apt. B., Wrightsville Beach, N.C. 28480 (Self-collected marine).
- Nybakken, Dr. James, Moss Landing Marine Laboratories, Box 223, Moss Landing, CA. 95039.
- Oatis, Bona D., 312 Holiday Park Dr., Pittsburgh, PA. 15239 (World marines; exchange).
- Ode, Dr. Helmer, 4811 Braeburn Dr., Bellaire, TX. 77401 (Gulf of Mexico marines).
- Oesch, D. Ronald, 9 Hill Dr., Glendale, MO. 63122 (Missouri mussel zoogeography).
- Oetzell, Miss Edith M., 518 S. Ardmore Ave., Villa Park, IL. 60181 (*Conus*).
- Old, William E. Jr., Dept. of Mollusks, American Museum of Natural History, Central Park W. at 79th St., New York, NY. 10024.
- Oliveira, Dr. Maury Pinto de, Dept. Biologia-Malacologia, Universidade Federal, De Juiz De Fora, Cidade Universitaria, 36100 Juiz de Fora, Minas Gerais, Brazil.
- Olsen, Philip L., 10708 Blossom Lane, Silver Spring, MD. 20903 (Cape Hatteras to Cape Cod mollusks).
- Oppenheimer, Dr. Ella H., 7703 Crossland Rd., Baltimore, MD. 21208.
- Orchard, C.D., P.O. Box 115, McQueeney, TX. 78123.
- Ostheimer, Alfred J., III, 1030 Mansion Ridge Road, Santa Fe, N.M. 87501.
- Pagel, Robert and Lorene, 5 South Grand Ave., Deerfield, WI. 53531 (Culture—intensive, extensive).
- Palmer, Dr. Katherine V.W., 206 Oak Hill Rd., Ithaca, NY. 14850.
- Parker, James Larry, 8705 Valleybrook Rd., Birmingham, AL. 35206 (Caribbean molluscs).
- Parker, Robert S., Freeport Sulphur Co., Box 26, Belle Chasse, LA. 20037.
- Parmalee, Dr. Paul W., Prof. of Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916 (Freshwater mollusks from archaeological sites).
- Parodiz, Juan Jose and Esther, 409 Ruthwood Ave., Pittsburgh, PA. 15227 (Neotropical mollusks and fresh water gastropods of U.S.A.).
- Pearce, Timothy A., 4104 Gull Harbor Road NE. Olympia, WA. 98506 (Ecology and distribution of land mollusks of the Pacific Northwest).
- Pena Monardez, Renan D., Av. Argentina 252, Dpto. 11, Antofagasta, Chile (Taxonomy, morphology and land snails).
- Penchaszadeh, Dr. Pablo E., INTECMAR, Universidad Simon Bolivar, Caracas, Venezuela (Apartado Postal 80.659).
- Petit, Mr. and Mrs. Richard, P.O. Box 30, North Myrtle Beach, SC. 29582 (World shells).
- Petranka, John G., 101 Morgan Bldg., Univ. of Kentucky, Lexington, KY. 40506 (Ecology and systematics of terrestrial gastropods).
- Petuch, Dr. Edward J., Dept. of Zoology, Univ. of Maryland, College Park, MD. 20742 (Zoogeographer).
- Pierce, Dr. Harold G., Rt. 2, Box 67B, Lexington, VA. 24450 (Local fauna interest).
- Pipher, Phyllis and Bernard T., 1116 N. St. Tekamah, NE. 68061 (Collectors especially of cones, *Murex*, volutes).
- Piplani, Shirley A., 26 Jameson Place, West Caldwell, NJ. 07006 (Chitons).
- Pondick, Jeffrey S., Biological Sciences Group, Univ. of Connecticut, Storrs, CT. 06268 (Studying the effects of parasites on marine mollusks).
- Porter, Hugh J., UNC Inst. Marine Sciences, Morehead City, NC. 28557 (Systematics, culture of bivalves).
- Post, Mrs. Alfred P. Jr., P.O. Box 65, Darlington, MD. 21034.
- Powell, Dr. Eric N., Dept. of Oceanography, Texas A&M University, College Station, TX. 77843 (Pyramidellidae; benthic ecology).
- Pratt, W.L. Jr. and Suzann Denton Pratt, Museum of Natural History, Univ. of Nevada, Las Vegas, 4505 Maryland Pkwy. S., Las Vegas, NV. 89154.
- Prezant, Robert S., College of Marine Studies, Univ. of Delaware, Lewes, DE. 19958 (Anomalodesmata; mantle structure and function/evolution).
- Pulley, Dr. Thomas E., Director, Houston Museum of Natural Science, P.O. Box 8175, Houston, TX. 77004.
- Quigley, (Mrs.) Jacqueline Stocksdales, 3502 North 93rd St., Omaha, NE. 68134 (Cypraeidae and related species; also studying the use of shells in other civilizations; fossil shells).
- Quinn, James F. Jr., Marine Research Laboratory, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Trochidae and Turridae).
- Raeihle, Dorothy and George, 211 Milligan Rd., West Babylon, NY. 11704.
- Rathjen, Dr. Warren F., National Marine Fisheries Service, X1109, Gloucester, MA. 01930 (*Cephalopods*).
- Raup, Timothy A., 910 Farrell Ave., Kalamazoo, MI. 49007 (*Conus*).
- Ray, Diana J., 542 Ledge Road, Seekonk, MA. 02771.
- Raymond, Torrance, C., 99 Ridgeview Rd., Poughkeepsie, NY. 12603.
- Reader, Mr. and Mrs. William R., 4772 49th Ave. North, St. Petersburg, FL. 33714 (Live mollusks).
- Reeder, Dr. Richard L., Faculty of Nat. Sci. Univ. of Tulsa, Tulsa, OK. 74104 (Land pulmonates).
- Reehm, Ms. Avon A., Box 3421, Galveston, TX. 77552.
- Rehder, Dr. Harald A., 5620 Ogden Rd., Washington, D.C. 20016.
- Rice, Thomas C., Of Sea and Shore Publications, P.O. Box 33, Port Gamble, WA. 98364.
- Richards, Charles S., Biomedical Research Institute, 12111 Parklawn Drive, Rockville, MD. 20852 (Freshwater mollusks, host-parasite relations, mollusk pathology and genetics).
- Rios, Dr. Eliezer de C., Box 379, Museo Oceanografico, Rio Grande, RS. 96200, Brazil.
- Ritchie, Mrs. Robert M., 17 Country Club Pl., Bloomington, IL. 61701.
- Roach, Frank and Joan D., 1028 Belvoir Rd., Norristown, PA. 19401 (Specializing in *Cardium*, *Chama* and *Pecten*).
- Robbins, Beth S., 415 Penn Road, Wynnewood, PA. 19096 (Bahamas).
- Roberts, Mr. and Mrs. H. Wallace, Hopkinson House, Apt. 2816, Washington Square South, Philadelphia, PA. 19106 (Marine).
- Robertson, Dr. Robert, Dept. of Malacology, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (Marine).
- Romberger, Penroe H., 615 Wayne Dr., Mechanicsburg, PA. 17055 (Emphasis on Conidae, Trochidae, and Murexidae).

- Root, John, P.O. Box 182, West Palm Beach, FL. 33402.
- Roper, Dr. Clyde F.E. and Ingrid, Dept. of Invertebrate Zoology, USNM - Smithsonian, Washington, D.C. 20560 (Systematics and ecology of the Cephalopoda).
- Ropes, John W., 21 Pattee Rd., East Falmouth, MA. 02536.
- Rosewater, Dr. and Mrs. Joseph, Dept. Invert. Zoology (Mollusks), USNM, Smithsonian, Washington, D.C. 20560.
- Roth, Barry, Dept. of Invert. Zoology, Calif. Academy of Sciences, San Francisco, CA. 94118.
- Rotter, Saul D., M.D., 130 Sunrise Ave., Palm Beach, FL. 33480 (Cones, Volutes, Cowries, Olives).
- Roworth, Edwin C., 1361 Windsor Rd., Cardiff-by-the-Sea, CA. 92007 (World shells and sea life).
- Rule, Patricia L., Asst. Marine Fisheries Biologist, Div. of Marine Fisheries, 18 Heritage Prof. Bldg., Sandwich, MA. 02563.
- Runnels, Randy J., Rt. 2, Box 2576, Brazoria, TX. 77422 (Gulf of Mexico mollusks, esp. gastropods).
- Russell, Dr. Henry D., 50 Springdale Ave., Dover, MA. 02030.
- Russell, Dr. Lois S., Royal Ontario Museum, 100 Queen's Park, Toronto, Ont., Canada M5S 2C6.
- Russell-Hunter, Dr. W.D., Dept. of Biology, 112 Lyman Hall, Syracuse Univ., Syracuse, NY. 13210.
- Rutter, Kurt L., P.O. Box 107, Stanton, NJ. 08885 (Shells of the littoral area).
- Sage, Walter E. III, 1123 Hathaway, Louisville, KY. 40215.
- Sartor, James C., 5606 Duxbury, Houston, TX. 77035 (Microscopic marine mollusks - exchange or purchase).
- Schell, Frederic B. Jr., 1200 Peppertree Lane, Apt. 102, Sarasota, FL. 33581 Nov. 1 to June 1; The Brooklands, Colebrook, CT. 06021 June 1 to Nov. 1.
- Scheltema, Dr. Amelie H., Woods Hole Oceanographic Institution, Woods Hole, MA. 02543 (Aplacophora).
- Scheuerman, Clara, 1366 Twinsburg Rd., Macedonia, OH. 44056 (*Harpa*, *Cypraea*, helmets).
- Schilling, Mr. and Mrs. Albert E., 419 Linden Ave., Glenside, PA. 19038 (Mr., *Cypraea*; Mrs., *Murex*; both, *Conus*).
- Schilling, Mrs. Frieda, 3707 Lan Dr., St. Louis, MO. 63125.
- Schmidt, John E., P.O. Box 403, Cookeville, TN. 38501 (Mussels of the Cumberland River system).
- Schriner, Miriam W. and Howard Jr., Rt. #2, Box 127, LaBelle, FL. 33935 (Paleo-malacological research).
- Seip, William F., 1555 Stonewood Rd., Baltimore, MD. 21239.
- Serrill, Linda and Richard, P.O. Box 207, Matagorda, TX. 77457 (Shells of the Matagorda Peninsula, TX).
- Shasky, Donald R., M.D., 834 Highland Ave., Redlands, CA. 92373.
- Shaw, William N., 209 Sycamore Ave., Easton, MD. 21601 (Shellfish culture).
- Shimek, Dr. Ronald, Dept. of Biological Sciences, Univ. of Alaska, 3221 Providence Dr., Anchorage, AK. 99504 (Turrid gastropods, gastropod systematics, subtidal benthic marine ecology).
- Shoemaker, Alan H., 330 Shareditch Rd., Columbia, SC. 29210 (Marine gastropods).
- Sibley, Frederick D., 196 Christopher St., Montclair, NJ. 07042.
- Sickel, Dr. James B., Biol. Dept. Murray State Univ., Murray, KY. 42071 (Unionidae ecology and physiology).
- Siddall, Scott E., School of Marine Sci. BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Physiological ecology of bivalves, particularly marine mussels and mariculture of mussels).
- Siekman, Mrs. Lula B., 5031 41st St., St. Petersburg, FL. 33711.
- Skinner, Drew V. Jr., P.O. Box 208, Bremerton, WA. 98310.
- Skoglund, Carol, 3846 E. Highland Ave., Phoenix, AZ. 85018 (Panamic Province shells).
- Smith, Douglas G., Dept. of Zoology, Morrill Science Center, Univ. of Mass., Amherst, MA. 01003 (Land and freshwater mollusca of NE North America).
- Smith, Ellen C., 16 Cromeset Rd., Wareham, MA. 02571.
- Smith, Dr. Francis A., 1023 55th Ave. South, St. Petersburg, FL. 33705 (Microscopic marine mollusks of Florida).
- Smith, Mrs. Hattie Little, P.O. Box 1053, Foley, AL. 36535 (Gulf of Mexico).
- Smith, Dr. Judith Terry, 1527 Byron St., Palo Alto, CA. 94301.
- Smith, Lawrence C., 51 Coppertree Lane, Babylon, NY. 11702.
- Smith, Mrs. Muriel F.I., National Museum of Natural Sciences (Malacology), Ottawa, Ont., Canada K1A 0M8.
- Smith, Vivienne B., Rt. #1, Box 90, Bokeelia, FL. 33922.
- Smrcek, Dr. Jerry C., 3316 King William Dr., Olney, MD. 20832 (Effects of pollution on freshwater mollusca).
- Snyder, Martin Avery, 745 Newton Rd., Villanova, PA. 19085.
- Sohl, Dr. Norman F., 10629 Marbury Rd., Oakton, VA. 22124.
- Solem, Dr. Alan, Dept. of Zoology, Field Museum of Nat. History, Chicago, IL. 60605.
- Sparks, Richard E., Box 599, Havana, IL. 62644.
- Sphon, Gale G. Jr., Los Angeles County Museum, Invertebrate Zoology, 900 Exposition Blvd., Los Angeles, CA. 90007.
- Stansbery, Dr. David H., Museum of Zoology, Ohio State Univ., 1813 North High St., Columbus, OH. 43210 (Naiads).
- Stanzione, Mrs. Antonetta R., 55 Green Ave., Barrington, R.I. 02806 (Studying shell life in the balance of nature).
- Starnes, Lynn B. and Wayne C., TVA Forestry Bldg., Norris, TN. 37828 (Zoogeography of southeastern U.S. mollusks).
- Steger, Mrs. Dan, 2711 68th St. N., Tampa, FL. 33619 (Marine fauna of Gulf of Mexico).
- Stein, Dr. Carol B., Museum of Zoology, Ohio State Univ., 1813 North High St., Columbus, OH. 43210 (Naiads, Gastropoda).
- Stelzig, Theresa (Mrs. O. Cline), 109 Duke Lane, Portland, TX. 78374.
- Stephens, Susan B., 425 Lighthouse Way, Sanibel, FL. 33957 (Muricidae and Vasidae, recent and fossil).
- Stern, Dr. Edward M., Dept. of Biology, Univ. of Wisconsin-Stevens Point, Stevens Point, WI. 54481 (Systematics and ecology of terrestrial gastropods and Unionidae).
- Steward, Supt. Orville M., P.O. Box 450, Briarcliff Manor, NY. 10510.
- Stingley, Dale V., P.O. Box 113, LaBelle, FL. 33935.
- St. John, Dr. Mary Ellen and Dr. F. Lee, 155 Van Tassell Ave., Newark, OH. 43055 (Naiads, esp. *Actinonais ligamentina*).
- Strenth, Dr. Ned E., Dept. of Biology, Angelo State Univ., San Angelo, TX. 76901 (General ecology, systematics, and larval development of opisthobranch molluscs of the Genus *Aplysia*).
- Stresau, Mary Ann, c/o Pilon, 1720 Kingsburg, Dearborn, MI. 48128 (Yacht "Sabot"/Panama, Caribbean).
- Strieder, Dr. Denise J., 143 Laurel Rd., Chestnut Hill, MA. 02167 (American shells).
- Sullivan, Joseph E., Bureau of Economic Geology, Univ. of Texas, University Station, Box X, Austin, TX. 78712.
- Sutow, Dr. Wataru W., 4371 North MacGregor Way, Houston, TX. 77004 (*Strombus*; exchange).
- Tate, Mrs. Mildred, 211 Huisache, Lake Jackson, TX. 77566.
- Taxon, Mr. and Mrs. Albert, 1300 NE 191st St., Apt. 211, North Miami Beach, FL. 33179.
- Taylor, Dr. Dwight W., Tiburon Center for Environmental Studies, P.O. Box 773, Tiburon, CA. 94920.
- Taylor, Myra L., 7602 McCullough Ave., San Antonio, TX. 78216 (Shells of the Texas coast).
- Taylor, Dr. Ralph W., Dept. of Biological Science, Marshall University, Huntington, W.VA. 25701 (Mussels of W.VA. and KY., land snails of W.VA.).

- Teskey, Mrs. Margaret C., P.O. Box 273, Big Pine Key, FL. 33043.
- Theiler, James L., 2020 Overlook Pass #7, Middleton, WI. 53562 (Paleoecological interpretation through mollusks).
- Thomas, Georgia and Jim, RD #2 Linvale Rd., Box 214, Ringoes, NJ. 08551 (Worldwide specimens emphasis on *Cypraea*, *Murex*, Volutes, Cones; also interest in the migration and feeding habits of mollusks).
- Thomas, Dr. Grace, Dept. of Zoology, Univ. of Georgia, Athens, GA. 30602 (Sphaeriids).
- Thomas, Miss Marguerite T., P.O. Box 721, Swansboro, NC 28584.
- Thompson, Dr. Fred G., Florida State Museum, Gainesville, FL. 32601 (Land and freshwater mollusks; systematics).
- Tippett, Dr. and Mrs. Donn L., 10281 Gainsborough Rd., Potomac, MD. 20854 (Western Atlantic, living and fossil - Cones, *Murex*, scallops, Fissurellidae).
- Toll, Ronald B., Rosenstiel School of Marine and Atmospheric Science - BLR, 4600 Rickenbacker Causeway, Virginia Key, FL. 33149 (Systematics of Cephalopods).
- Tomlinson, Mrs. Marjorie R. and Robert S., 4400 East-West Highway, Bethesda, MD. 20014.
- Tomba, Dr. Alex S., Museum of Zoology, Univ. of Michigan, Ann Arbor, MI. 48109 (Land and freshwater mollusks).
- Treece, D. Granvil, University of Texas Marine Science Institute, Port Aransas, TX. 78373 (Molluscan systematics; taxonomy; zoogeography).
- Trinidad, Dr. Victor Jose V., 22040 Westhampton, Oak Park, MI. 48237 (Cowries, Cones, Olives and Tibias).
- Tunnell, Dr. John W. Jr., Corpus Christi State Univ., Corpus Christi, TX. 78411 (Systematics, distribution and ecology of reef and bank molluscs of Gulf of Mexico).
- Turgeon, Dr. Donna D. and Dr. Kenneth W., Marine Science Consortium, Box 16, Wallops Island, VA. 23337 (Marine bivalves (planktonic to adult) systematics and ecology).
- Turner, Dr. Ruth D., Museum of Comparative Zoology, Harvard Univ., Cambridge, MA. 02138.
- Underwood, Harold T., Dept. of Biology, Texas A&M University, College Station, TX. 77843 (Interested in molluscs as they serve in the capacity as hosts in parasite life cycles).
- Vagvolgyi, Dr. Joseph, Biology Dept., College of Staten Island, B-204, 715 Ocean Terrace, Staten Island, NY. 10301 (Evolutionary theory; zoogeography).
- Vail, Dr. Virginia, 607-28 Dixie Dr., Tallahassee, FL. 32304.
- Van der Schalie, Dr. Henry, 15000 Buss Rd., Manchester, MI. 48158.
- Van Devender, Amy S., Rt. 4, Box 261-B, Boone, NC. 28607 (Land Snails).
- Van Heukelem, Dr. W.F., Horn Point Environmental Laboratories, Univ. of Maryland, P.O. Box 775, Cambridge, MD. 21613 (growth, bioenergetics, aging, life-history and behavior of Cephalopods).
- Vecchione, Michael, 104 Birch Circle, Williamsburg, VA. 23185 (Ecology and systematics of pelagic molluscs).
- Vega, Dr. Luis Eduardo, 420 S. Essex Ln., Tucson, AZ. 85711.
- Vercoe, Harold John, 201 Chamberlain St., Raleigh, N.C. 27607 (Ecology, taxonomy).
- Vidrine, Malcolm F., 313 Davis St., Jennings, LA. 70546 (Fresh water mussels of Louisiana; study of water mites).
- Villarreal, Dr. Maria M., Instituto de Ingenieria, Dept. Ing. Ambiental, APDO 70-472, Mexico 20, DF., Mexico.
- Virji, Ashiraf, 8000 Ramsgate Ave., Los Angeles, CA. 90045 (*Cypraea*, Cones, Volutes).
- Vokes, Dr. Harold E. and Dr. Emily H., Dept. of Geology, Tulane Univ., New Orleans, LA. 70118 (Mesozoic and Tertiary mollusks; fossil and recent Muricidae).
- Voss, Dr. Gilbert L. and Nancy A., Div. of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Cephalopods—systematics and life history of pelagic squids).
- Wagner, Robert J.L. and Frances E. (nee Fran Williams), RD #1, Box 21, Marathon, FL. 33050.
- Walker, R. Lindsay Jr., Apartado 06 Postal 344, San Salvador, El Salvador, Central America.
- Walklet, Gerrie, Randolph Farms, #1401, 13300 Indian Rocks Rd., Largo, FL. 33540.
- Waller, Dr. Thomas R., Dept. of Paleobiology, Smithsonian, Washington, D.C. 20560 (Zoogeography, ecology, evolution of Cenozoic Pectinidae).
- Walsh, Lyle, College of Marine Studies, Lewes, DE. 19958 (Calcium transport as related to calcification).
- Walter, L.J., 6349A Columbia Pike, Baileys Crossroads, VA. 22041 (hobby).
- Warmke, Germaine L., 1711 S.W. 43rd Ave., Gainesville, FL. 32607 (Mollusks of the Caribbean).
- Warren, Dr. Sol L., 375 Garden Blvd., Garden City, NY. 11530.
- Wasili, Mrs. John (Odessa), P.O. Box 187, Frisco, NC. 27936.
- Waters, Ruth A., 150 Barker Hill Dr., RFD 3, Guilford, CT. 06437 (U.S. marine, principally E. Coast).
- Way, Carl Michael, 275-H SE Lilly Ave., Corvallis, OR. 97330 (Ecology and Physiology of the Sphaeriidae and freshwater gastropods).
- Wayne, Dr. William J., M.H. 412, Dept. of Geology, Univ. of Nebraska, Lincoln, NB. 68588 (Pleistocene non-marine mollusks).
- Webb, Dr. Glenn R., Rt. 1, Box 1158, Fleetwood, PA. 19522.
- Webb, John A. and Rhoda, 5031 Redcliff Court, Dunwoody, GA. 30338.
- Weingartner, Mathilde P., 17 Amelia Court, Staten Island, NY. 10310.
- Weisbord, Norman E. and Nettie S., Dept. of Geology, Florida State Univ., Tallahassee, FL. 32306 (Cenozoic and recent).
- Weiss, Harold M., 3607 Sarah Dr., Wautagh, NY. 11793 (Conidae and Cypraeidae).
- Welty, Stephen L., Box 639, Dubois, WY. 82513.
- Werner, Milton, 70 Richmond St., Brooklyn, NY. 11208.
- West, Dr. Ronald R. and L.E. (Lois) Gundrum, Dept. of Geology, Kansas State Univ., Manhattan, KS. 66506.
- Westcott, Russell T., 24 Duke Dr., Stamford, CT. 06905 (general study of marine mollusks).
- Westerfield, Mrs. Asher L., Apt. C203, 429 Montgomery Ave., Haverford, PA. 19041 (Marine shells).
- Wheel, Adlai B. Sr., 4501 West Seneca Turnpike, Syracuse, NY. 13215.
- White, Kenneth J., R.Ph., 2587 Ballew Ct., Marietta, GA. 30062 (Caribbean Province shells).
- Whiteside, Mrs. Smith (Jeanne), Rt. 3, Box 902-G, Merritt Island, FL. 32952.
- Williams, Mrs. Edward P. (Linda), Crosstrees Hill Road, Essex, CT. 06426 (Collecting, preservation of mollusks and their habitats).
- Williams, Dr. James D., 2318 Hiladrose Dr., Silver Spring, MD. 20902 (Freshwater mussels; zoogeography and systematics).
- Williams, Mrs. Margaret A., Rt. 3, Box 28A, Sarasota, FL. 33580 (Caribbean and miniature).
- Williamson, Catherine, 4026 Willow Dr., Corpus Christi, TX. 78411 (Natural history - ecology).
- Willis, Jeffrey A., 402 Kings Highway, Lewes, DE. 19958.
- Wilson, John M., 28014 Green Willow, Farmington Hills, MI. 48018.
- Wilson, Mrs. Bill T., P.O. Box 191, Ingleside, TX. 78362 (Strombidae; amateur collector).
- Wilson, Dr. Druid, Room 501, U.S. National Museum, Washington, D.C. 20560.

- Windnagel, John, 3581 Snouffer Rd., Worthington, OH. 43085 (Florida shells).
- Winger, Dr. Parley V., U.S. Fish and Wildlife Service, CNFRL - Field Research - Athens; School Forest Resources; Univ. of Georgia, Athens, GA. 30602.
- Withrow, Mr. and Mrs. Carl C., 6720 35th Terr. N., St. Petersburg, FL. 33710.
- Wolfe, Dr. Douglas A., 68-A Wild Horse Circle, Pine Brook Hills, Boulder, CO. 80302 (W. Atlantic marine).
- Wood, Delbert M. and L. Jean, 206 Scarborough, P.O. Box 342, Sidney, IL. 61877 (Unionidae, *Pecten*, *Cypraea*, *Murex*, land snails).
- Work, Robert C., 7610 S.W. 63rd Court, South Miami, FL. 33143.
- Wright, Bill, 1473 Woodland, Abilene, TX. 79605 (*Cypraea*).
- Wright, Kirk E. and Andrew, Box 2191, Fitchburgh, MA. 01420.
- Wright, Fran, 11422 S.W. 113th Place, Miami, FL. 33176.
- Wu, Shi-Kuei and Ching-Chen, c/o Univ. of Colorado Museum, Boulder, CO. 80309 (Functional morphology of mollusks; Muricid

- gastropods; land and freshwater mollusks of Rocky Mountain area).
- Wurtz, Dr. Charles B., 3220 Penn St., Philadelphia, PA. 19129 (Terrestrial Pulmonata).
- Yochelson, Dr. Ellis, E. 501, U.S. Museum of Natural History, Washington, D.C. 20560.
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- Young, Mrs. Ann Frame, P.O. Box 2559, Marathon Shores, FL. 33052 (Scuba; Cassidae).
- Young, Carl T. Jr., 621 Chase, Corpus Christi, TX. 78412.
- Young, Donald J., 11975 3 St., East, Apt. 5, Treasure Island, FL. 33706 (Collecting, photographing and studying marine mollusks).
- Young, H.D. and Wilma G., P.O. Box 1931, Seattle, WA. 9811 (Exchange Pacific Northwest gastropods; also purchase).
- Young, M.E. (Miss), P.O. Box 29, Falls Church, VA. 22046 ("The Shell Cabinet" owner).
- Zager, Mrs. Jane, 519-C Crooked Lake Lane, Fort Pierce, FL. 33450 (American shells).

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- Baba, Dr. Kikutaro, Shigagaoka 35, Minami-11-jo, Sang-cho, Ikoma-gun, Nara-ken, Japan 636 (Opisthobranchia - taxonomy, morphology).
- Boletsy, Sigurd, Ph.D., Laboratoire Arago, F-66650 Banyuls-sur-Mer, France (Cephalopod biology and development).
- Bosch, Dr. Donald, 9088 Mina Al Fahal, Muscat, Sultanata of Oman.
- Bylund, Gwen, P.O. Box 2, Manama, State of Bahrain, Arabian Gulf (Cones, cowries from the Indian Ocean—Mauritius).
- Cain, Dr. Arthur J., Dept. of Zoology, University of Liverpool, P.O. Box 147, Liverpool, England L69 3BX.
- Cataldo, J., Rue deCouthiol, 26250 Livron/Drome, France (Cowries).
- Franchini, Mr. Dario A., Via Cremona 37, I46100 Mantova, Italy (Mediterranean mollusks (Muricacea, Epithonacea, general)).
- Fuziwaru, Tugio, Kamihiranomae kobayasi City, Miyazaki Prefecture, Japan.
- Habe, Tadashige, National Science Museum, Hyakunin Cho Shinjuku Ku, Tokyo 160, Japan.

- Kessner, Vince, P.O. Box 1340 Townsville 4810, Queensland, Australia.
- Lee, Jacques Kim, 2 Preston Road, West Wimbledon, London, England SW 20 OSS (*Cypraea*, *Conus*, *Oliva*, *Voluta*, *Harpa*, rare shells).
- Miyauti, Dr. Tetuo, Miyademy Fisheries Lab. Mitsu, Futamicho, Watarai-gun, Mie-ken, 519-06 Japan.
- Orlando, Vittorio Emanuele, via Palermo 168, 90049 Terrasini (Pa), Sicilia, Italy.
- Otero, D. Jose Hernandez, Capitan Quesada, S/N, Galdar (Gran Canaria), Espana.
- Paget, Dr. Oliver E. Naturhistorisches Museum, Burgring 7, A-104, Vienna, Austria.
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- Upatham, Edward Suchart, Ph.D., Biology Dept., Faculty of Science, Mahidol Univ. Bangkok 4, Thailand.
- Wong, Mr. H.Y., Flat 1 D, Ewan Court, 54 Kennedy Road, Hong Kong.

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U.S. DEPARTMENT OF COMMERCE, NOAA, Library and Inf. Service Div., 6009 Executive Blvd., Rockville, MD. 20852.
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NOTICES

The Fiftieth Anniversary of the founding of the American Malacological Union, Inc., will be celebrated at the Forty-Seventh Annual Meeting July 19-25, 1981, at Ft. Lauderdale, Florida, with headquarters at the Galt Ocean Mile Hotel. A major symposium is planned on "Functional morphology and ontogeny of mollusca as applied to higher category systematics." Interested participants are asked to contact President Richard S. Houbbrick, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560. A symposium on endangered mollusca and a refresher course on Paleozoic and Mesozoic mollusca are also planned. There will be a book-shell auction. Shell clubs sponsoring this meeting are Broward Shell Club, Palm Beach County Shell Club, and Greater Miami Shell Club.

How to Study and Collect Shells, latest edition of the popular symposium published by the American Malacological Union, may still be purchased for \$2.50 each from Paul Jennewein, Corresponding Secretary, Box 394, Wrightsville Beach, N.C. 28480. A special discount of fifty percent is offered for purchases of six or more copies (postage additional). U.S. funds are requested for overseas orders, plus postage.

The INDEX TO THE BULLETINS OF THE AMERICAN MALACOLOGICAL UNION, through 1974, may be purchased from Treasurer Myra L. Taylor, 7602 McCullough Ave., San Antonio, TX. 78216, for \$5.00 postpaid. U.S. funds are requested for overseas orders.

A few copies remain of the reprint from *Malacologia* of the SYMPOSIUM ON RARE AND ENDANGERED MOLLUSKS, a session of the AMU 1968 meeting, and are available from Recording Secretary Constance E. Boone, 3706 Rice Blvd., Houston, TX. 77005, for \$1.25 postpaid in U.S. postal zones. U.S. funds and postage requested for overseas orders.

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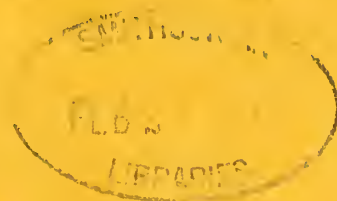
Freshwater Mollusks by David Stansbery
Terrestrial Mollusks by Fred Thompson
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Marine Aquaria by Michael J. Sweeney

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**BULLETIN OF
THE AMERICAN
MALACOLOGICAL
UNION**

for 1981

**FIFTIETH
ANNIVERSARY**



**Ft. Lauderdale, Florida
July 19-25, 1981**

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Please put your mailing address on your manuscript; editor must be able to reach you.

**BULLETIN OF
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**FIFTIETH
ANNIVERSARY**

**Ft. Lauderdale, Florida
July 19-25, 1981**

FIFTIETH ANNIVERSARY





FIFTIETH ANNIVERSARY

**Ft. Lauderdale, Florida
July 19-25, 1981**

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Joshua L. Baily, Jr.
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Louis N. Goethel
Adaline C. Westerfield
W. W. Sutow

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A FOOTNOTE TO THE HISTORY OF MALACOLOGY IN THE UNITED STATES

A. Myra Keen

Department of Geology, Stanford University, CA 94305

Mrs. Martha B. Williamson of Los Angeles, California, was an active malacologist around the turn of the century. After she died in 1922 her collection went to the Los Angeles County Museum. What became of her extensive correspondence I do not know, except that one small box of it was brought to Stanford University by a friend of hers for deposit in the Stanford library's archives.

Among the Williamson material were some letters of special interest to us during the AMU's 50th anniversary — from the founder of the American Association of Conchologists, John H. Campbell of Philadelphia. First, he sent to her a printed flyer that was the initial membership list and memorandum to early members. Dated April 26, 1890, the list comprises 29 names, with addresses and statement of special interests. John H. Campbell heads the list as President, interest Cypraeidae. Charles W. Johnson is secretary, interest South American mollusks. Among the 27 others one notes most of the professionals of the time. Below the list Mr. Campbell wrote a special note to Mrs. Williamson: "10 additional to May 5, including yourself." A transcription of this flyer forms an appendix to the present note.

The actual correspondence consists of five letters from Mr. Campbell in a span of eight months. Did he, one wonders, find time to write so often to all the members? Perhaps Mrs. Williamson's replies (not preserved) whetted his enthusiasm.

LETTERS FROM JOHN H. CAMPBELL, ATTORNEY, TO MRS. M.B. WILLIAMSON

Philadelphia, May 5, 1890. Madam: Yours of 28th ult. received. We are much pleased to have your name upon the rolls of the Assoc. You are the first lady enrolled, although we expect several others. By same mail with your letter came one from Prof. Josiah Keep, Mills College, Cal., so that there are now 2 Californians on the list. The Assoc. is growing rapidly and has now 39 members — pretty good for less than five weeks work! There seems to be a field for the Association and I trust it will accomplish some useful results. We shall be pleased at any time to hear from you.

May 21, 1890. — Thanks for kind letter. As to suggestions you make, I think it would be well to defer action upon them until we have gathered in nearly all the conchologists in America, which at the present rate of progress is likely to take place before the end of the year. We have now 55 members and still they come. The Association must be filling a want, for it seems to be popular from the start.

Nov. 11, 1890. — Thanks for the kindly offer, but we promised when we started the Association that the members should be at no expense. I had long thought that persons interested in shells were not doing effective work because of isolation and that if we could get them to associate in systematic study, science would be benefitted — and for that reason I broached the idea of our Association. At the end of a year we might be able to hold a convention and then we could provide for a small annual payment to cover expenses and could also elect a prominent scientist as president, instead of an amateur like myself. We would have done so in the beginning but we thought it better to

put a business man, used to organization, in at first to get the association started, and afterwards we could replace him by a prominent scientist.

I am glad you take kindly to the idea of a U.S. Collection, and you can help it materially. I would suggest that you send 1) some very *small* specimens of the Haliotidae, as we have already some magnificent *big* specimens; 2) a pair of fine *H. assimilis* Dall; 3) suites of the Pacific Coast Fissurellidae, except *Luca-pina crenulata*, which we have.

Dec. 1, 1890. — Your list of San Pedro shells will be exceedingly valuable and I will be much pleased to receive a copy when published. If all the members would prepare similar lists, how easy it would be to straighten out the nomenclature of American shells!

When I go to the Academy next, I will count the number of species of *Haliotis* in the collection and send you word. It is a very fine and large collection, but with assiduity and perseverance you can readily excel it.

I have mailed an invitation to Mr. Weeks of Brooklyn and hope to enroll him. I had already sent one to Dr. DeCamp but have not as yet received a reply. Mr. E.H. White, Astoria, Oregon has joined, and by the way, Dr. J.G. Cooper, Haywards, Cal. has also joined, at which I am very much pleased. Members are coming in rapidly; 12 have been added since the pamphlet and some 20 new members have been suggested.

The U.S. Collection will be a great success. We have already half filled our second case, and the specimens are very fine. . . . If you ever get East, you will be delighted to see how creditable to the Association the Collection is.

Jan. 15, 1891. — I regret very much that your request not to announce your donations in *Nautilus* arrived too late. Mr. Pilsbry had promised to send me a proof of the association article but failed to do so. I think it would be well, though, to announce your donations with the others, but of course will comply with your wishes if you insist on it in the future.

Thank you for your promise to ask Dr. Cooper for his list of fossils.

In January *Nautilus* I announced my list of catalogues, with the Haliotidae. If you find any errors in it, kindly let me know. We must endeavor to straighten out the nomenclature if we can.

You might send, from time to time for the Collection, if you have them to spare, the Fissurellidae. *Fissurella volcano* Reeve is the only species, thus far, received from West Coast.

Mr. G.W. Lichtenthaler is now in San Francisco, and will probably be there for a month or more yet. He will doubtless collect some fine things for the Collection.

What happened to the Association and to the Collection? We may guess that the latter may have been merged into the holdings of the Philadelphia Academy, but why, after so brisk a start, did the Association evaporate? Did failing health dampen Mr. Campbell's zeal? He died, according to Dr. R. Tucker Abbott's "American Malacologists," only a few years later, in January, 1897, at the age of 50. But why did no one else take over care of the infant organization? Perhaps it was that the time

was not right. Surely it would seem that this willing and ambitious amateur, working in the malacological metropolis of Philadelphia, had a viable society under way. Contrast the early demise of the American Association of Conchologists with the burgeoning of the American Malacological Union 40 years later, when another amateur, Norman W. Lermond, who lived in relative isolation in Maine, pointed out in a few letters to East Coast workers the need for a formal society. That time the suggestion was like a seed that fell on fertile ground and took root.

AMERICAN ASSOCIATION OF CONCHOLOGISTS

List of members: April 26, 1890

John H. Campbell, President,
740 Sansom St., Phila.Cypraeidae
Charles W. Johnson, Secty.,
Wagner Institute, Phila.S. American moll.

Frank C. Baker, Acad. Nat. Sci., PhiladelphiaMuricidae
Theo. G. Brinton, 755 Corinthian Ave., Phila.Mitridae
F.C. Browne, Framingham, Mass.Nassidae
H.F. Carpenter, 29 Page St., Providence, R.I.Moll. of R.I.
Prof. Wm. B. Clark, Johns Hopkins Univ.,
BaltimoreEocene moll.
Wm. H. Dall, U.S. Natl. Museum,
Washington, D.C.Abyssal moll.
Rev. A. Dean, Munsey, Pa.Fusidae
George W. Dean, Kent, OhioStrepomatidae
John Ford, Philadelphia, Pa.Olividae
Geo. W. Harper, Woodward High School,
Cincinnati, O.Land & f.w. shells
Dr. W.D. Hartman, West Chester, Pa.*Partula*, etc.
A.A. Hinkley, Dubois, Ill.Strepomatidae
Rev. A. Kendig, 11 Hanson Pl., Brooklyn, N.Y.*Amphidromus*
F.R. Latchford, 19 Elgin St.,
Ottawa, Ont.Limnaeidae, N. Amer.

James R. Morison, Lexington, Va.Specific variation
Wm. J. McGinty, Philadelphia, Pa.Marginellidae
H.A. Pilsbry, Acad. Nat. Sci. Philadelphia ...Land & f.w. shells
S. Raymond Roberts, Glen Ridge, N.J.Cypraeidae
Edward W. Roper, Revere, Mass.Cypraeidae
John Shallcross, Philadelphia, Pa.Volutidae
J.A. Singley, Giddings, Tex.Land shells, N. Amer.
Charles T. Simpson, U.S. Nat. Museum,
WashingtonGeogr. distr.; nomencl.
Uselma C. Smith, 707 Walnut St., PhiladelphiaConidae
Bryant Walker, 18 Moffatt Block,
Detroit, Mich.Land & f.w., N. Amer.
Rev. John Walton, Lakeside, N.Y.Cypraeidae
R.P. Whitfield, American Mus. Nat. Hist., N.Y.Fossil moll.
Joseph Willcox, 1810 Chestnut St., PhiladelphiaFulgur

To the members

Phila., Apr. 26, 1890

The Association is meeting with great favor and evidently seems to supply a want. As you will see by the foregoing list, the Association is growing rapidly and if the members will interest themselves in sending to me additional names of persons who would make suitable members, there is no reason why the membership should not reach 100 in a very short time.

Any suggestions looking to the advancement of the Association will be gladly received by

Yours very truly,
John H. Campbell

You will be notified from time to time of further additional membership.

(Note by Myra Keen: A printed membership list of the Association dated Oct. 1, 1890, was given to Stanford University library by Mrs. Ida Oldroyd in the 1930's.)

HALF-CENTURY OF AMU 1931-1981

Margaret C. Teskey

The American Malacological Union began as an idea in the fertile mind of Mr. Norman Lermond, an energetic and individualistic Norwegian gentleman who operated a small natural history museum and arboretum in Thomaston, Maine. After discussing the merits of such an organization with his good friend, William J. Clench of Harvard ("Over a bowl of chop suey!" recalls Dr. Clench), he dispatched the first of a series of letters to every person of his acquaintance of whom he had knowledge as being in any way interested in mollusks or their shells.

Response was so favorable that he named his movement the American Association of Conchologists, and called a meeting to organize. The meeting was held by invitation of Dr. Henry A. Pilsbry at the Academy of Sciences in Philadelphia, in April, 1931. By then 169 persons had sent in dues of twenty-five cents and were enrolled as charter members, and 29 of them attended the organizational meeting. Six charter members remain with

the AMU, and three attended the half-century meeting.

A constitution was drafted and adopted, the name American Malacological Union proposed and accepted, and Dr. Pilsbry was elected to be the first president after Mr. Lermond had declined the office. He chose instead to be Corresponding Secretary, but was not active. Soon his duties were incorporated with those of Financial Secretary Imogene S. Robertson of Buffalo, aided by her husband, Harold.

The following year a meeting was held at the U.S. National Museum at Washington, D.C. Several additions were made to the Constitution, and Dr. Paul Bartsch elected to succeed Dr. Pilsbry and to conduct the 1933 meeting at Harvard.

Over the following decade the AMU grew slowly but at a steady pace. Annual meetings were held at Stanford University (Junius Henderson, President), Buffalo Museum of Science (President Clench being out of the country and so unable to preside, the meeting was conducted by Vice-President Calvin

Goodrich), St. Petersburg, Florida (Goodrich), University of Michigan (Joshua L. Baily, Jr.), University of Havana, Cuba (Carlos del a Torre), Royal Ontario Museum of Zoology in Toronto, Canada (Maxwell Smith), again at the Academy of Natural Sciences in Philadelphia (H.B. Baker), then at the invitation of Mr. Lermond, at Rockland, Maine (Harald A. Rehder).

A part of the program at the Maine meeting (1941) was in the form of a collecting symposium, and several papers were read on the subject of the collecting of land, freshwater and marine mollusks. The Annual Report (a continuing publication) in which these papers were printed was a handy reference source, so much in demand that in 1955 the symposium papers were incorporated into the first printing of the popular AMU publication, *How to Collect Shells*.

World War II interrupted annual meetings for a period of four years, but by carrying on voluminous correspondence Imogene Robertson was able to compile and issue annual report bulletins for 1943 and 1944-45; in this last was reported the death of Norman Lermond at age 83.

The 1946 meeting was the twelfth, and a return visit to the U.S. National Museum; since President Louise M. Perry had resigned, Vice-President Henry van der Schalie occupied the chair. It was an especially joyous occasion, as old friends and new gathered to exchange news and experiences after so long an absence.

The offices of Corresponding and Financial Secretaries had been held by Mrs. Robertson since the second year; at this meeting they were formally incorporated into one and her husband, Harold R. Robertson, elected to fill the newly created office of Treasurer.

The following year the AMU met for the second time on the Pacific coast, at Asilomar in Pacific Grove, in California. President van der Schalie again conducted the meeting, and on this occasion the idea of forming a west coast division was broached. It received such favor that the following year (1948) the Pacific Division of the American Malacological Union was organized, and held the first annual meeting at Stanford University.

The AMU convened that year at the Carnegie Museum at Pittsburgh (A. Myra Keen) and during the succeeding years at the University of Miami (Elmer Berry), Chicago Natural History Museum (Fritz Haas), then again at the Museum of Science, Buffalo (J.P.E. Morrison).

Harold Robertson had passed away earlier that year (1951), and Mrs. Robertson had assumed his duties along with her own. Her health, however, was failing and at the meeting in August she tendered her resignation. Termination of her long and faithful service was accepted with regret, and upon her recommendation Margaret C. Teskey was made Secretary-Treasurer.

Mounting interest was increasingly evident as local shell clubs were organized in Chicago, New York, Florida, Texas. Currently sixty-six such groups are in existence in America, and the annual accounting of their activities attests to the fact that the collection and study of shells holds a reward for all.

Annual AMU meetings continued with ever-mounting attendance. The Museum of Comparative Zoology at Harvard was re-visited in 1952 (Jeanne Schwengel), then for the first time meetings were held at the University of Kansas (A. Byron Leonard), the University of New Hampshire (Joseph C. Bequaert), and at Wagner College on Staten Island, New York (Morris K. Jacobson).

A revised Constitution was adopted in 1954, containing a clause relating to the Pacific Division and its precepts; in 1956 that group postponed its annual meeting and went all out to entertain the AMU at a deluxe hotel in San Diego (Allyn G. Smith). Peabody Museum at Yale University provided the site for the 1957 meeting (Ruth D. Turner). Dr. Pilsbry attended this meeting but died three months later at the age of ninety-five.

A repeat visit to the University of Michigan was made the following year (Aurele La Rocque), then for the third time the AMU returned to its birthplace in Philadelphia (R. Tucker Abbott). Redpath Museum at McGill University at Montreal, Canada, hosted the 1960 convention (Katherine V.W. Palmer), and next year the AMU paid a third-time visit to the U.S. National Museum (Thomas E. Pulley). St. Petersburg again in 1962 (William K. Emerson) and the following year a third visit was made to the Buffalo Museum of Science (Albert R. Mead).

By now the AMU had achieved a recognized place among the scientific societies of the world, and listed among the corresponding members were names from such distant lands as Japan, the Philippines, Australia, Saudi Arabia, Yap, the Netherlands. Today, twenty years later, may be added Germany, France, Oman, New Zealand, South Africa, Brazil, Belgium, Ireland, Taiwan, Thailand, Hong Kong, Austria, Arabian Gulf. The annual report Bulletins have become a valued reference source since they contain abstracts and full papers of most of the papers read at annual meetings, together with a constantly updated membership list with current addresses.

The AMU went to New Orleans in 1964 as guest of Louisiana State University in New Orleans (John Q. Burch), and adopted an extensive constitution, incorporating the By-Laws of the Pacific Division. Next year an invitation to return to Wagner College on Staten Island was accepted (Juan J. Parodiz), and the annual report of this meeting contained an index of all papers read since 1949.

By now membership approaching 800 had created an intolerable workload for Secretary-Treasurer Teskey, though relieved of a portion of her duties when in 1954 the Executive Council had created a new office, that of Publications Editor. George M. Moore was elected to fill it, succeeded in 1962 by Karl Jacobson who held the office until 1972 when he resigned and his duties assumed by Arthur H. Clarke. In 1962 the office of Secretary-Treasurer was separated and Jean M. Cate was elected AMU Treasurer, a post she held for three years. She was succeeded by Mae Dean Richart who resigned in 1966 and Mrs. H.B. Baker elected. She served until 1972, then upon her resignation Myra Taylor was elected to the office, a post she now holds. Arthur H. Clarke served as Publications Editor from 1972 to 1975, when succeeded by Dee Dundee. Marion Hubbard served as Secretary from 1970 to 1974. Paul R. Jennewein was made Corresponding Secretary in 1971, and Constance E. Boone became Recording Secretary in 1974. Dundee, Taylor Jennewein and Boone continue to serve today and seem to have consolidated into a highly regarded body to conduct AMU business and produce the AMU Bulletin.

So the years rolled by, the annual AMU meetings red letter days on the calendar of most of the country's malacologists, professional and amateur alike. The friendly attitude of the professional malacologist towards the amateur has long been remarked upon, creating camaraderie reflected by the success of half a century of happy reunion.

The 1966 meeting at the University of North Carolina

(Ralph W. Dexter) was such a meeting, as was the next when the AMU went north to meet in Ottawa, Canada at the invitation of the National Museums of Canada (Leo G. Hertlein). Then to Corpus Christi, Texas in 1968 (Arthur H. Clarke), when six Texas shell clubs united to play host in lieu of university auspices. The Pacific Division became inactive during this year and was declared dissolved in 1972.

The University of Wisconsin welcomed the AMU to its campus at Marinette (Joseph Rosewater), and at this meeting in her home town Secretary Teskey tendered her resignation to become effective the following year when the meeting was held in Key West, Florida (Alan G. Solem). A much amended and revised constitution was adopted at this 1970 meeting.

The 1971 meeting was again held in Florida, at Coco Beach (David H. Stansbery). The following year Texas again beckoned, this time to Galveston (Arthur S. Merrill); The University of Delaware hosted in 1973 (Dee S. Dundee) and the following year Harold D. Murray occupied the chair at the Museum of Science at Springfield, Massachusetts.

A joint meeting with the Western Society of Malacologists was held in 1975, when President Donald R. Moore shared his duties with WSM President George Radwin at San Diego State University, San Diego, California. And now the years pass evermore rapidly: Ohio State University, Columbus, Ohio (Dorothea Franzen, 1976); Naples, Florida as guests of the Naples Shell Club (George M. Davis, 1977); University of North Carolina again, this time at Wilmington, North Carolina (Carol

B. Stein, 1978). Again joint with WSM when, as guests of Coastal Bend Shell Club the meeting was held at Corpus Christi, Texas (William E. Old, Jr., 1979); Louisville, Kentucky and hosted by the Louisville Conchological Society (Clyde F.E. Roper, 1980).

This then to 1981 and the conclusion of a half-century of AMU when at Ft. Lauderdale, Florida President Richard S. Houbrick occupied the chair and at the annual dinner introduced Charter Members, Dr. William J. Clench, Dr. Harald Rehder, and Allen F. Archer. Three others were unable to be present: Katherine van Winkle Palmer, Carlos G. Aguayo, Aurele LaRocque.

Attendance at the annual meetings averages about twenty-five percent of total membership. A program of diversified scientific papers has been followed from the beginning, though of recent years an effort is being made to group some of them into symposia. Conservation is being stressed, though to date the effort to convince shell collectors not to take live mollusks seems confined to lip service. The World Health Organization's programs of medical malacology, commercial interests served by research on behalf of the National Shellfisheries Association, promotion of mollusk-related science in schools and universities - all, together with many others, are being aided by the work of AMU. Also aided are untold numbers of people who love shells for their beauty alone. Truly, Norman Lermond built better than he knew!

THE AMERICAN MALACOLOGICAL UNION, INC.

FORTY-SEVENTH ANNUAL MEETING

JULY 19-25, 1981
ST. PETERSBURG, FLORIDA

A record 219 persons registered for the 50th Anniversary of the American Malacological Union and its 47th Annual Meeting at Fort Lauderdale, Florida, July 19-25, 1981.

Not all stayed the entire week, but most of them participated in the portions in which they were interested. Although the Galt Ocean Mile Hotel had bookings from other groups — tourists from Germany, Holland and France — AMU members stood out with their badges, parties and other gatherings, sufficiently to dominate activities at the beachfront hotel.

The 50th opened unofficially with the opening of a bunch of fifths or half-gallons at the President's Reception in the ground-floor suite at the end of one of the wings of the four-story hotel. Leaving the smoke-filled rooms, many escaped to the lawn overlooking the beach. That night, the ocean, in the absence of a breeze, appeared to resemble a huge inland lake. A few tried to cool off with iced drinks, much to their sorrow the following morning. However, at the time, most developed a warm feeling of companionship with those whom they'd last seen about a year earlier. And President Richard S. Houbrick played the perfect host.

The South Florida Shell Clubs, which made arrangements for the meeting under the leadership of Gene D. Everson, had prepared a bounteous supply of finger food for the party and many a member who arrived Sunday evening made supper of the delicious tidbits. Most unusual was the smoked marlin which many thought was smoked turkey and ate with considerable relish. One of the members of a host club had caught the fish the day before and smoked the meat that night and the morning of the party. The marlin disappeared rapidly. But there were platters of other tasty food and fruit that lasted into early morning.

Part of the pre-meeting festivities was the showing of slides taken over the years and assembled by Mrs. Pat Armes of the Broward Shell Club. They were shown early Sunday afternoon. Because of the popular demand, however, the show was repeated during the subsequent two days.

A swim in the ocean (temperature 79 degrees) was an excellent way to wake up in the morning. The ocean was about 50 feet from the back of the hotel at high tide. And a few of the members had also brought snorkels and flippers, swimming out to the reef to look at fish, collect coral and try to find mollusks.

Secretary Constance Boone and Treasurer Myra L. Taylor pitched in the following morning to help with registration. "Goody" bags, assembled by the busy arrangements committee, provided plenty of collecting bags, pens and pencils, combs, cards, key rings, maps and information.

The Conservation Committee met, followed by the meeting of the Council of Systematic Malacology (the group of curators and museum directors involved in malacology. Dr. Fred G. Thompson, as chairman, was reelected.

President Houbrick opened the meeting early Monday afternoon. Presented was a scroll with red ribbon, seals and fancy writing from the Malacological Society of London with greetings on the 50th Anniversary.

Dr. Gilbert L. Voss, Rosenstiel School of Marine and Atmospheric Science, University of Miami, welcomed the AMU to Southeast Florida, noting it was a unique area bordering on

the tropical range.

He recalled that his family had been involved in malacology ever since his grandfather had sent barrels of shells from South Florida to the Smithsonian Institution. From that point on, he recalled other leaders in the field who had worked and had written about South Florida's ocean, fossil and land mollusks.

He warned would-be shell collectors traveling by boat in the southern parts of the Bahamas to travel either in large groups of boats or operate in the waters in the daytime.

"Don't get caught at night between Bimini and the outer reef or off Andros Island in a boat," he said. "Officials in the Bahamas can't provide protection."

After Dr. Voss' talk, Dr. Houbrick opened the Symposium on Morphology with an explanation of what a symposium really was in ancient Greece. The word comes from "sym," meaning with, and "posis," meaning drinking. Symposium also referred to the vessel associated with wine drinking most significantly. Singing, music and conversation was also part of a symposium in ancient Greece.

The opening speaker, Bill Heard, started things off with a bang. The public address system shorted out with flames, an explosion and smoke. Then there was a loud hum, similar to a feedback, until the system was unplugged. The speaker confessed that electronics and AMU meetings have had peculiar effects on his talks. During the meeting at the University of North Carolina at Wilmington in 1976, the loudspeaker system blew up when he tried to speak.

Technicians arrived later to put the system back in working order by the next day, when as many as three sessions were conducted simultaneously.

Monday afternoon's session included a talk by Arthur Cain of the University of Liverpool, England, on flipping land snails. Slides showed the bottom of one variety was different from its upper coloration system, the difference being a protective device. When magpies dropped a slippery snail, chances are they would be looking for the color pattern remembered of the upper or lower portion found originally and overlook the other pattern, resulting from the flipped snail. Patterns varied with habitat. Cain's conclusion resulted from examining 3,460 snails.

Other speakers from abroad included Simon Tillier of the National Museum d'Histoire Naturelle, Paris; Winston Ponder of the Australian Museum, Sydney; Vera Fretter of the University of Reading, England; Anders Waren of the University of Goteborg, Sweden; Victor Scarabino of the Instituto de Investigaciones Biologicas "C. Estable," Montevideo, Uruguay; Philippe Bouchet of the Museum National Historie Naturelle, Paris; Pablo Penchaszadeh of Simon Bolivar University, Caracas, Venezuela; P.R. Boyle, University of Aberdeen, Scotland, and John S. Peel of the Geological Survey of Greenland, Copenhagen, Denmark.

Monday night's Texas Party took the edge off the heat and enabled the later arrivals to become acquainted with those already there. One accident marred the evening as Mrs. Selma Lawson fell over a low table and broke her hip. She spent the rest of the week in the hospital.

Tuesday the triple session continued. The Morphology

Symposium went on in the Continental Room, where the temperature remained about 60 degrees. Fresh water papers were read in a warmer room. And John Root of West Palm Beach set up a salt water aquarium, and filled it with gastropods, bivalves, brittle stars, coral, hermit crabs, mud crabs, starfish and sea urchins.

The group picture on the beach after lunch brought the colorfully dressed members into the bright, hot sunshine. The picture was taken on color film. Some had put bathing suits on under their picture clothes and remained on the beach to sample the warm Atlantic waters. Papers resumed in three concurrent sessions after the picture was made and the group excused. Shell talks for amateurs were offered in the afternoon for those who might not have been interested in the scientific papers.

Tuesday evening's program concerned fossil mollusks. Ellis Yochelson and Robert Linsley of the Paleontology and Stratigraphy Branch, Department of the Interior, and Colgate University, led the talks.

Wednesday's sessions narrowed down to the coin-flip type — marine papers and workshops on collecting and identifying shells. The workshops concerned first fossil shells and then fresh water ones. Edward Petuch led the fossil session; Fred Thompson, the fresh water session.

In the afternoon, marine papers were presented in the cool Continental room, while papers on fossil research and terrestrial snails were given in the smaller, warmer rooms.

Wednesday evening's program consisted of recollections of the start of the organization. Speakers were Harald Rehder and William Clench. These were followed by the book and shell auction to raise funds for future symposia.

Rehder recalled 29 persons attended the first meeting of the AMU 50 years ago and credited Norman W. Lermond of Maine as the "father of AMU and its guiding hand" along with the person first conceiving the idea for the organization. The idea was first developed in Yung Lee's Restaurant off Harvard Square, Cambridge, Mass.

After the idea had been knocked around, Charles C. Allen, Dan Emery and Lermond gathered on Jan. 8, 1931, met in St. Petersburg, Fla., and launched the national Society of American Conchologists. Plans were made for the first meeting, set April 30 - May 2, at the Academy of Natural Sciences in Philadelphia. The name was suggested as the Association of American Conchologists.

Obtaining a list of 168 persons interested in conchology, Emery sent invitations. Also proposed as a name was the Conchology Society of America. On April 30, 1931, 29 people came to the meeting in Philadelphia, where Henry A. Pilsbry was elected president of the American Malacological Union. Thirteen papers were read.

Illustrations of the people who first formed the AMU were shown by Clench.

Auctioneers were Bill Old, Gary Magnotte and R. Tucker Abbott. The total was \$3,147.60.

The symposium on Endangered Species was held Thursday, led by Arthur H. Clarke. The papers concerned mostly fresh water and land snail varieties. Also holding forth were the marine bivalve enthusiasts in one room and the *Cephalopod* boosters in another room.

Thursday evening's informal session consisted of an illustrated talk by Dr. Donald Bosch on shell collecting in the Gulf of Oman, near the Persian Gulf. He was introduced by Bill Old, who had originally encouraged him to send shells to the American Museum of Natural History in New York when the physician was working in the Arabian emirate of Oman. Archie Jones of Miami showed slides of hybrids of Florida Tree Snails which he raised. Bea Winner of North Palm Beach gave an illustrated talk

on molluscan egg cases.

Friday's papers were delivered in two concurrent sessions — fresh water in the Continental room and marine papers in the smaller rooms.

The Annual Business Meeting, presided over by Houbrick, was held in the afternoon. Richard E. Petit of North Myrtle Beach, S.C., was thanked for his financing of symposia through the sale of shell stamp cards and cancelled envelopes. The 1982 annual meeting will be held in New Orleans July 19-23 and that of 1983 in Seattle, Wash., at the University of Washington, Aug 7-13. Next year's symposia will be on genetics.

A total of 203 persons were announced as being at the banquet Friday night. Providing banquet favors were Archie Jones, Dr. Harry G. Lee of Jacksonville, Mary Palmer of Pompano Beach, Johnnie Johnson of Merritt Island and Charlotte Lloyd of Jacksonville Beach. They included tree snails, fresh water shells, fossil shells, pecten and other marine shells.

Anne Joffe of Sanibel created the centerpieces for the banquet tables.

Chairman Everson of the local committee recognized leaders and their contributions. They included Jean Andrews, Neil Hepler, Mary Palmer, David Pugh, Dr. Harry G. Lee, Fran Wright, R. Tucker Abbott, Ellie Tash, John Root and Dr. Donald Moore. He also recognized five shell clubs for their combined efforts. They were the Broward Shell Club, Palm Beach County Shell Club and Greater Miami Shell Club, all co-hosts; Jacksonville Shell Club and Ft. Myers Shell Club.

Dr. Ruth D. Turner was the banquet speaker and showed slides and a silent film on trips to the Galapagos Rift aboard the *CHALLENGER* and the discovery of a new mussel at one of these, 2,500 meters down. She also described what was seen from the Research Submersible *ALVIN* in a deep dive. (During the talk a bulb blew out on a projector, but a spare bulb was installed so the show could go on).

Houbrick announced the winner of the special cash award for the best student paper as Frank E. Perron, Department of Zoology, University of Hawaii, Honolulu. In his paper, he described lab rearing studies on the larvae of *Conus* in planktonic growth rate and pelagic growth. Differences in sizes are related to variation in egg size. Perron had left early to make flight connections and missed hearing he'd won.

Climaxing the annual meeting were field trips Saturday by bus, car and boat.

Those leading individual sessions during the week included Robert Robertson, Jim Nybakken, Ellis Yochelson, Fred Thompson, Carol Stein, Tom Waller, Gil Voss, George Davis and Ruth Turner.

Club representatives were Dr. Thomas Burch for the Hawaiian Malacological Society; John Root, Palm Beach County Shell Club; Florence Kuczinski, St. Petersburg Shell Club; Jay J. Tripp, Pittsburgh Shell Club; Paula Mikkelsen, Astronaut Trail Shell Club; Stephen L. Welty, Pacific Northwest Shell Club; Bernice Emerson, Galveston Shell Club; Gertrude Moller, Jacksonville Shell Club; Lt. Col. Corrine Edwards, Greater Miami Shell Club; Gene D. Everson, Broward Shell Club; William E. Old, Jr., New York Shell Club, and Charlotte Lindar Gorbunoff, Chicago Shell Club; Theresa Stelzig, Coastal Bend Shell Club; Peggy Williams, Sarasota Shell Club; Dr. Eliezer C. Rios, Brazilian Malacological Society; Edward Nieburger, Boston Malacological Club; Gary Rosenberg, Philadelphia Shell Club.

Paul R. Jennewein
Corresponding Secretary

CONTRIBUTED PAPERS

PRESENTED AT THE 1981 MEETING

CORRELATIONS OF SHELL SHAPE OF *ELLIPTIO WACCAMAWENSIS*, *LEPTODEA OCHRACEA* AND *LAMPSILIS* SP. (BIVALVIA, UNIONIDAE) WITH ENVIRONMENTAL FACTORS IN LAKE WACCAMAW, COLUMBUS COUNTY, NORTH CAROLINA.

Karen J. Horn and Hugh J. Porter

University of North Carolina at Chapel Hill,
Institute of Marine Sciences
Morehead City, N.C. 28557

ABSTRACT

Obesity (shell width/shell length) values for *Elliptio waccamawensis*, *Leptodea ochracea*, and *Lampsilis* sp. from Lake Waccamaw, Columbus County, North Carolina were analyzed for correlations with sediment characteristics and for regional variation. *E. waccamawensis* and *L. ochracea* showed no significant correlations with mean sediment size, percent organic matter, or percent CaCO_3 in the sediment. *Lampsilis* sp. was positively correlated with percent organic matter in the sediment. The uniformity of obesity of these three indigenous species of naiads does not coincide with regional habitat variability within Lake Waccamaw.

INTRODUCTION

Observations of the effects of stream size and stream flow on shell form have been made by Ortmann (1920), Ball (1922), and Mueller (1926). The subject was expanded upon by Grier (1920), Eagar (1948), and Clarke (1973) to include comparisons of lake and flowing water forms of common species. Emphasis was then placed on factors within a habitat instead of the habitat in general. Correlations were established between shell form and the environmental variables: temperature, substrate type, trophic level, latitude, and water chemistry by Howard (1922), Brown, Clark, and Gleissner (1938), Agrell (1949), Cvancara (1969), and Green (1972).

Lake Waccamaw, the largest natural lake in North Carolina, located in Columbus County, belongs to a group called the North Carolina bay lakes. Physical descriptions of Lake Waccamaw and the other bay lakes are found in Frey (1948, 1949) and Louder (1958). The known molluscan fauna of Lake Waccamaw in 1978 was ten bivalve species and three species of gastropods, several endemic to the lake (Stansbery and Clench, 1978). A 1978 - 1980 survey of the molluscan fauna of Lake Waccamaw by the authors included quantitative observations of the lake habitat. Statistical analyses of effects the environment has on the native fauna have been made from these observations.

This paper discusses correlations between specific sediment characteristics and obesity of three native bivalve species living in Lake Waccamaw. Also examined is the variability of obesity between various regions with the lake.

METHODS

Benthic samples (700+) were taken from throughout Lake Waccamaw using a diver-operated suction-type dredge. Samples were collected from within 1/16 and 1/4 m² sampling

frames and screened through 1.6 and 6.4 mm mesh screening bags attached to the dredge. Dredge samples were taken at quarterly intervals throughout the year. Additional samples were collected monthly by hand-screening samples from within a 1/8 m² sampling frame through a 1.6 mm sieve screen. For further information on sampling methods see Porter and Horn (1980).

Bivalves were pegged open and preserved in "AGW", a mixture of 90% ethyl alcohol, glycerin, and water (16:3:1), shortly after collection. In the laboratory, bivalves were opened and sex and gravid condition were determined. Measurements of length and width used a dial calipers.

Sediment samples were collected, to a maximum depth of 12 cm, at the site of each dredge or hand-screen sample and analyzed using a loss-on-ignition procedure to determine percent organic matter and percent CaCO_3 by weight. Measurements of mean sediment size utilized a series of U.S.A. Standard Testing Sieve Screens and a portable sieve shaker. The lake was divided by the authors into regions based on lake orientation, depth, and sediment characteristics.

Bivalve names are those used by Dr. D.H. Stansbery of the Ohio State University Natural History Museum (pers. comm.) and identifications were authenticated by Dr. Stansbery. Considered in the study are three native Lake Waccamaw bivalves, *Elliptio waccamawensis* (Lea, 1863), *Leptodea ochracea* (Say, 1817), and *Lampsilis* sp.¹

RESULTS

The term obesity (shell width divided by shell length) has been used by Ortmann (1920), Grier and Mueller (1922), and Brown, Clark, and Gleissner (1938) to compare the shell form of individual bivalves. In Lake Waccamaw, obesity was not correlated with shell length ($r=0.033$, $N=150$).

Obesity of the Lake Waccamaw bivalves and the relationship of it to examined variables is presented in Table I. *Elliptio waccamawensis* and *Leptodea ochracea* were not significantly correlated with either mean sediment size or percent CaCO_3 in the sediment. A slight positive correlation (95% significance level) did exist between obesity and the percent organic matter in the sediment for both species. Obesity of *Lampsilis* sp. was positively correlated with percent organic matter at both 95% and 99% levels. No correlations were evident with mean sediment size or percent CaCO_3 in the sediment.

Analysis of variance was used to compare the obesity of bivalves found in various regions of the lake (Table II). Analysis of the four major regions (shallow sand, intermediate sand, deep sand, and peat) (Fig. 1) for significant differences in shell obesity resulted in F-values of 0.131, 0.296, and 0.129 for *E. waccamawensis*, *L. ochracea*, and *Lampsilis* sp. respectively, all nonsignificant. Division of the lake into subregions is shown on Fig. 1. No F-value was significant except that of *E. waccamawensis* in the peat region and *L. ochracea* in the intermediate sand region (Table II). Both of these values were sig-

¹*Lampsilis* sp. is currently being studied by Dr. D.H. Stansbery, Ohio State University. Description and species name are forthcoming.

Table I. Correlations of Mean Obesity With Sediment Characteristics

Species	Mean Sediment Size		Percent Organic Matter		Percent CaCO ₃	
		d.f.	r	d.f.	r	d.f.
<i>E. waccamawensis</i>	-0.006	1564	0.157*	1522	0.018	1522
<i>L. ochracea</i>	0.013	214	0.149*	217	0.022	217
<i>Lampsilis</i> sp.	0.053	110	0.322**	111	-0.017	111

* significant at the 95% level

** significant at the 95% and 99% levels

nificant at the 95% and 99% levels.

Table III contains the mean obesity of the three bivalve species subdivided into the categories: males, gravid females, and non-gravid females. Mean values showed no significant variation in obesity between sexual categories for each species.

DISCUSSION

The majority of previous research has dealt with the comparison of shell form in different environments. Ortmann (1920) established that the "more obese form is found farther down in the large rivers, and passes gradually, in the upstream direction, into a less obese form." Findings by Ball (1922) and Eagar (1948) substantiated this statement. Grier and Mueller (1926) noticed the tendency of three species of naiads to become more convex in the lower reaches of rivers. Increasing convexity carried with it an increase in obesity. Comparison of flowing water and lake forms of the same species was treated by Grier (1920) in Lake Erie and the Upper Ohio River, Grier and Mueller (1926) in the Mississippi River, and Clarke (1973) in the rivers and lakes of the interior Canadian basin. Both the Mississippi River and Ohio River studies showed a greater degree of inflation in the lake environment. In Canada, however, Clarke ob-

served just the opposite. The more inflated forms were found in rivers.

Other individual factors that may influence shell form have also been examined by others. Agrell (1949) stated "ecological shell variation is essentially a function of trophic degree". Certain shell proportions show an increase with increasing eutrophication. Through the use of scatter diagrams, Cvancara (1963) noted that at lower latitudes, obesity tended to increase. Brown, Clark, and Gleissner (1938) specifically selected sampling sites with different degrees of shoal exposure. More exposure resulted in a greater degree of shell stunting. Both Allen (1922) and Eagar (1948) conclude that the type of bottom is more important in determining shell shape.

The three species used in this study showed a surprising lack of variability in obesity throughout the lake. None of the F-values between regions showed significant differences. Although there was sufficient habitat variability to delineate these regions, apparently it was not sufficient to affect shell form. Division of the habitat regions into subregions (Fig. 1) was an attempt to separate effects of wave action due to prevailing winds and effects of varying shoreline development. Shoreline development includes lakefront housing, boat docks, some beach bulkheading, and recreational activities (i.e. boating, swimming, water-skiing, etc.). Greatest areas of wave disturbance is in subregions one, two, and six. The prevailing winds are usually from the southwest; only storms cause winds from the north. Shoreline development was heaviest in subregions one, five, and six. Subregions two and four were only moderately developed. Subregion three was undeveloped. Analysis shows significant variation for *E. waccamawensis* only between the two peat subregions. This was variability was probably due to factors not considered in this study. *L. ochracea* had a significant F-value in the intermediate sand subregions. Areas of greatest difference appeared to be subregions two and five. Region five was an area of heavier recreational use and higher disturbance, however, evidence is insufficient to suggest that this is the cause of the variability. Examination of sediment components showed no correlation with *E. waccamawensis*. *L. ochracea* was correlated with percent organic matter. This was only a slight positive correlation at the 95% level. No direct relationships can be drawn from these data. A positive correlation did exist between *Lampsilis* sp. and percent organic matter (significant at both the 95% and 99% levels). This may be a good relationship to pursue when establishing a distribution pattern for this species. Distribution patterns within the lake will be published later by the authors as part of the total findings of a

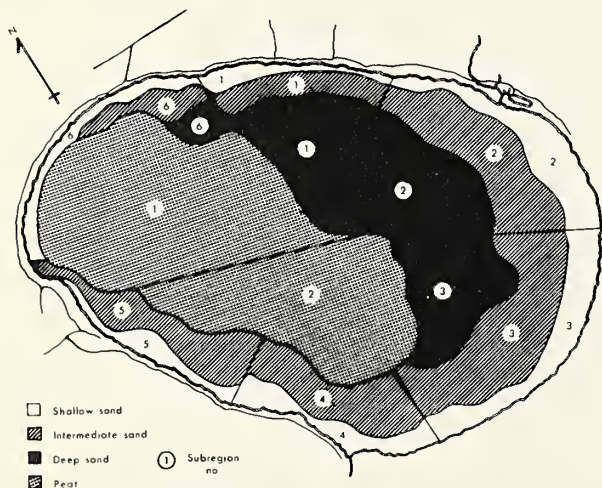


Figure 1. Regions and subregions of Lake Waccamaw

Table II. Mean Obesity Values in Various Subregions and Analysis of Variance of Major Regions of Lake Waccamaw.

Elliptio waccamawensis $\bar{X} = 0.38$ N = 1593

	Subregions						F	d.f.
	1	2	3	4	5	6		
Shallow Sand	0.38	0.37	0.39	0.37	0.38	0.38	0.52	5,268
Intermediate Sand	0.38	0.38	0.38	0.38	0.37	0.37	1.01	5,620
Deep Sand	0.37	0.37	0.38				2.53	2,402
Peat	0.37	0.39					9.20*	1,278

Leptodea ochracea $\bar{X} = 0.46$ N = 226

	Subregions						F	d.f.
	1	2	3	4	5	6		
Shallow Sand	0.44	0.46	0.46	0.42	0.45	0.45	0.41	5,72
Intermediate Sand	0.44	0.51	0.47	0.45	0.42	0.45	3.87*	5,54
Deep Sand	0.43	0.47	0.46			0.40	1.48	3,25
Peat	0.45	0.45					0.02	1,60

Lampsilis sp. $\bar{X} = 0.39$ N = 113

	Subregions						F	d.f.
	1	2	3	4	5	6		
Shallow Sand			0.38		0.38	0.41	0.58	2,6
Intermediate Sand	0.37		0.45	0.39	0.36	0.38	2.25	4,32
Deep Sand	0.39	0.39	0.39			0.38	0.27	3,40
Peat	0.39	0.39					0.01	1,22

* significant at the 95% and 99% levels

study of the Lake Waccamaw molluscan fauna.

Table III lists mean obesities for the three species when divided by sex and gravid condition. There was no significant difference in obesity values between the sexes. For this reason, all analyses were carried out using total bivalves, regardless of their category. This allowed for larger, and perhaps, more responsive sample sizes.

SUMMARY

E. waccamawensis, *L. ochracea*, and *Lampsilis* sp. showed a general lack of variability between the major regions of Lake Waccamaw. *E. waccamawensis* and *L. ochracea* were significantly different within the peat and intermediate sand regions respectively. At this time, no reason is apparent for this variability. Obesity of the three species was not correlated with either mean sediment size or percent CaCO₃ in the sediment. Some positive correlation was evident with percent organic matter, especially for *Lampsilis* sp. There was no difference in obesity due to sex or gravid condition among the three species.

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Table III. Comparison of Mean Obesity Among Sexual Categories

Species	Males (m)			Females (f)			Gravid Females (gf)			t-values		
	N	$\bar{X}$	S ²	N	$\bar{X}$	S ²	N	$\bar{X}$	S ²	m vs. f	f vs. gf	m vs. gf
<i>E. waccamawensis</i>	1070	0.375	0.062	408	0.371	0.057	115	0.371	0.072	0.29	0.004	0.16
<i>L. ochracea</i>	146	0.453	0.0019	50	0.463	0.001	30	0.452	0.0027	-1.49	1.18	0.11
<i>Lampsilis</i> sp.	84	0.391	0.002	21	0.382	0.0005	8	0.395	0.0006	0.90	-1.37	-0.25

THE MOLLUSCAN FAUNA OF COPPER CREEK (CLINCH RIVER SYSTEM) IN SOUTHWESTERN VIRGINIA

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Twenty species of freshwater mussels and three species of freshwater snails were found living in a 60-mile reach of Copper Creek. This survey is a continuing effort to document the Cumberlandian mussel fauna from tributary streams located in the southern Appalachian Mountains and the Cumberland Plateau region.

In general, the molluscan fauna of the tributary streams in the upper Clinch River system have been poorly studied. The most recent information concerning the mussel fauna of the Clinch River is contained in published and unpublished reports by Neves (1980), the Tennessee Valley Authority (1979), Bogan and Parmalee (1979), Bates and Dennis (1978), and Stansbery (1973, 1976a, 1976b, and 1976c). An excellent historical account of the mussel fauna from the upper Tennessee River drainage including the Clinch River was done by Ortmann (1918), and later by Cahn (1936), and Hickman (1937).

Copper Creek, located in southwestern Virginia, flows from Moccasin and Copper Ridges in Russell County westward into Scott County where it joins the Clinch River near Speer's Ferry, Virginia (Clinch River Mile 211.6). Copper Creek is approximately 60 miles long and has a drainage basin of 133 square miles.

This Clinch River tributary drains a small part of the Ridge and Valley physiographic province. The topography of this region consists of parallel ridges and valleys comprised mainly of folded shale and limestone formations which contain numerous sinkholes and extensive underground drainage channels (Masnik, 1975).

Copper Creek was surveyed to provide comprehensive,

up-to-date information on the status of Cumberlandian species and present or potential habitats as part of our Cumberlandian Mollusk Conservation Program (Jenkinson, 1981). The habitats necessary to support Cumberlandian species in many of the larger tributary streams have been reduced to a few isolated populations in the upper Tennessee drainage (Ahlstedt 1981; Ahlstedt and Brown 1980). Copper Creek remains relatively free from extensive human impacts except for some agricultural development in the watershed. In this respect, Copper Creek is perhaps one of many smaller tributary streams in the upper Tennessee River drainage system which contain unknown populations of mussels including Cumberlandian species.

During May 1980, TVA biologists surveyed the mollusk fauna of Copper Creek. The lower 13.8 miles of Copper Creek were surveyed by floating the entire reach in canoes. The upper reach was sampled at points of access because this reach of the stream was too shallow for canoes.

Collections were made at 36 sites over this 60-mile reach (Figure 1) using wading, snorkeling, and scuba diving sampling techniques. These collections document the existence of 20 species of freshwater mussels and three species of river snails in this stream (Tables 1 and 2). Eleven of the mussel species are Cumberlandian forms including two species (*Fusconaia cuneolus* and *Fusconaia edgariana*) listed as endangered by the U.S. Fish and Wildlife Service.

While mussels occurred throughout the 60-mile reach of Copper Creek, most species were found only between Copper Creek Mile (CCM) 1.4 (site 3) and CCM 5.9 (site 11). Most of the Cumberlandian species occurred at CCM 1.8 and CCM 2.1 (sites 4 and 5); however, four Cumberlandian species were relatively common throughout the length of Copper Creek (*Medionidus conradicus*, *Pleurobema oviforme*, *Villosa nebulosa*, and *Villosa perpurpurea*). While *Villosa perpurpurea* is common in Copper Creek, this species appears to be rare in much of the rest of the upper Tennessee River system. Recent TVA surveys have only revealed a few live specimens of this species in the upper Clinch River and in Beech Creek, a tributary to the Holston River near Rogersville, Tennessee. In addition, five Cumberlandian species are rare in Copper Creek:

Actinonaias pectorosa, *Dysnomia capsaeformis*, *Fusconaia cuneolus*, *Fusconaia edgariana*, and *Villosa vanuxemi* (Table 2).

The decline in species diversity above CCM 7.7 (site 15) may be related to the presence of Spivey Mill Dam which forms a barrier to migratory fish. The relatively small size of Copper Creek above this dam and the few points at which we sampled it between CCM 13.8 and CCM 40.1 (sites 21 and 29) may also have affected our results.

The snail fauna of Copper Creek consists of three species: *Anculosa subglobosa*, *Pleurocera uncialis*, and *Campeloma* sp. Both *A. subglobosa* and *P. uncialis* were common throughout the entire reach of Copper Creek that was surveyed (Table 2). *Campeloma* sp. was found at six sites and is probably limited in distribution because of its apparent preference for mud and sand habitat.

Table 1.

The location of all TVA 1980 sampling sites on Copper Creek by creek miles (CCM) and the number of species found at each site.

Site	Copper Creek Mile	Number of Species
1	0.2 mouth Copper Creek (Scott County, VA.)	3
2	0.9	5
3	1.4	11
4	1.8	18
5	2.1	17
6	2.3	10
7	2.7	7
8	3.5 Spivey Ford	10
9	4.5	7
10	4.8	12
11	5.9	9
12	6.3	2
13	7.0	4
14	7.3	5
15	7.7 Spivey Mill Dam	2
16	8.5	7
17	11.0	8
18	11.5	9
19	12.0 Highway 619 bridge	4
20	13.0	9
21	13.8	10
22	20.6	4
23	20.8 Highway 669 bridge	3
24	23.8	5
25	29.0	6
26	30.3	7
27	32.7	2
28	34.7 Dorton Fort	6
29	40.1	6
30	41.2	6
31	42.0	6
32	44.0	3
33	48.2 Russell County, VA.	6
34	49.7	5
35	51.1	7
36	53.0	3

In summary, at least 50 percent of the freshwater mussel fauna found in Copper Creek are Cumberlandian species indicating that "these" are not of any drainage system - only of the Clinch River. Smaller tributary streams are ecologically important parts of any drainage system and may provide an important source for mussel recolonization in larger river systems.

Acknowledgment

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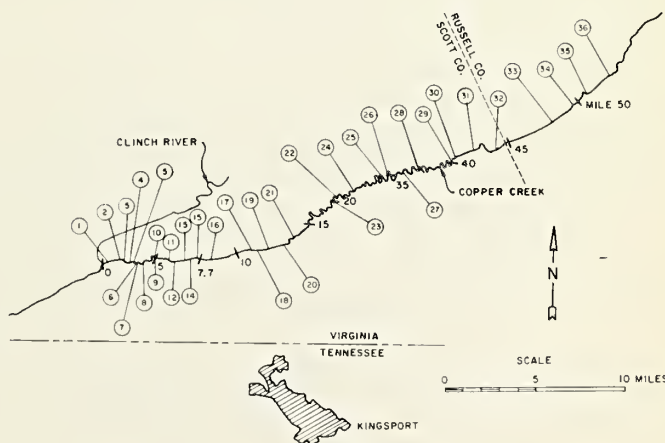


Figure 1: Copper Creek Mollusk Sampling Sites

Table 2. Number of each mollusk species found during qualitative sampling of Copper Creek, Virginia, May 1980.

SPECIES	COLLECTING SITES																																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Mussels:																																				
* <i>Actinonias pectorosa</i> (Conrad 1834)	-	-	1	-	-	-	2	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Alasmodonta viridis</i> (Rafinesque 1820)	-	-	-	1	3	-	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	1	-	-
<i>Amblesa costata</i> (Barnes 1823)	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Corbicula manilensis</i> (Philippi 1841)	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
* <i>Dysnomia capsaeformis</i> (Lea 1834)	-	-	1	1	4	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Elliptio dilatatus</i> (Rafinesque 1820)	-	-	9	6	4	13	2	6	-	1	1	-	-	-	-	2	-	3	-	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
* <i>Fusconaia barnesiana</i> (Lea 1838)	-	-	-	5	5	6	-	1	1	2	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
+* <i>Fusconaia cuneolus</i> (Lea 1840)	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
+* <i>Fusconaia edgariana</i> (Lea 1840)	-	-	-	3	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Lampsilis fasciola</i> (Rafinesque 1820)	1	2	-	4	2	2	2	2	2	1	-	-	-	-	2	-	1	2	-	-	-	-	-	3	1	1	-	1	-	1	-	-	-	-	7	-
<i>Lampsilis ovata</i> (Say 1817)	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Lasmigona costata</i> (Rafinesque 1820)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
* <i>Medionidus conradicus</i> (Lea 1834)	2	3	-	17	36	57	9	34	2	6	-	1	-	1	-	5	1	6	-	18	21	-	1	1	9	3	-	19	6	2	13	1	5	4	5	2
* <i>Pleurobema oviforme</i> (Conrad 1834)	-	-	5	32	7	3	1	3	1	11	5	2	-	-	23	11	11	11	32	23	1	-	34	23	8	1	21	1	4	26	24	4	5	25	-	-
<i>Ptychobranchus fasciolaris</i> (Rafinesque 1820)	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
* <i>Ptychobranchus subtentum</i> (Say 1825)	-	-	3	-	2	-	-	-	-	-	-	-	-	-	-	2	2	1	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Quadrula cylindrica</i> (Say 1817)	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
* <i>Villosa nebulosa</i> (Conrad 1834)	1	4	19	23	10	27	-	11	1	5	4	-	1	-	1	5	5	11	6	11	7	1	-	20	49	45	3	26	103	46	35	3	51	66	99	31
* <i>Villosa perpurpurea</i> (Lea 1861)	-	-	8	17	7	3	-	2	-	2	1	-	-	-	2	4	12	3	9	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
* <i>Villosa vanuxemi</i> (Lea 1838)	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Snails:																																				
<i>Anculosa</i> (=Leptoxis) <i>subglobosa</i> (Say 1825)	-	19	47	27	71	15	59	46	63	51	5	-	1	16	-	12	9	24	-	36	491	263	116	-	153	492	-	117	120	58	142	-	1	5	7	-
<i>Campeloma</i> sp.	-	-	-	1	-	-	-	-	-	2	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-
<i>Pleurocera uncinale</i> (Haldeman 1841)	-	4	52	36	9	4	43	60	30	26	6	-	-	33	-	8	10	47	-	48	219	88	82	-	7	50	-	11	78	70	19	-	33	16	97	53
TOTAL NUMBER OF SPECIES	3	5	11	18	17	10	7	10	7	12	9	2	4	5	2	7	8	9	4	9	9	4	3	5	6	7	2	6	6	6	6	3	6	5	7	3

*Cumberlandian forms (11)

†Endangered species (2)

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MATHEMATICAL MODELING OF THE SHELLS OF HIGHER PROSOBRANCHS

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The mathematical description of shell coiling in various invertebrate groups has long been a subject of investigation (for a review of early work see Thompson, 1942). Most recently, a model has been developed which describes the generalized coiled shell in terms of four parameters: the shape of the generating curve (S), the whorl expansion rate (W), the position of the

generating curve relative to the axis (D), and the rate of whorl translation (T) (Raup, 1961, 1966). This model has been used in graphical computer reconstructions of generalized shells (Raup, 1962; Raup and Michelson, 1965), as well as in studies of the distribution of actually occurring coiled shells in theoretically possible morphospace (Raup, 1965, 1967; Rex and Boss, 1975). Modified forms of several of these parameters were used by Vermeij (1971, 1973) in studies of the functional significance of shell shape, while the use of these parameters as taxonomic characters was explored by Kohn and Riggs (1975) in their studies on *Conus*.

In my attempts to apply this model to specific taxa within the

Buccinacea, I found that this model, as presently defined, has the following limitations: the shape of the generating curve (S) must be roughly circular or elliptical (i.e. not applicable to shells with a siphonal canal); when S is elliptical, one of the axes of the ellipse must be perpendicular to the axis of coiling. As these conditions are rarely met by higher prosobranchs, the purpose of this study is to expand and modify the existing parameters so as to obtain objective, reproducible and standard characters of general utility in taxonomic as well as in ecological and ontogenetic studies of shell morphology.

MATERIALS AND METHODS

The specimens to be analyzed were photographed in two orientations. In the first, the apertural (ventral) aspect, the shell was positioned so that the optical axis of the camera was perpendicular to the coiling axis and tangent to the shell periphery at a point on the outer lip midway between the suture and the posterior end of the siphonal canal. (fig. 1). The spire (posterior) aspect was photographed by orienting the optical axis along the coiling axis (fig. 2). Several specimens were also sectioned along a plane passing through the coiling axis and photographed so that the plane of section was parallel to the film plane (figs. 6, 9, 11, 13). All measurements were made on projected images of the negatives.

The coiling axis of the shell (fig. 3, A) was taken as the bisector of the spire angle (fig. 3, α). For shells with a siphonal canal, the line segment $\overline{ab}$ divides the siphonal canal from the body cavity, a and b being the points of inflection in the curvature of the columella and the outer lip respectively. Line segment $\overline{cd}$ demarcates the anterior end of the siphonal canal (fig. 3).

Major Axis (Maj) = length of the major axis of an ellipse approximating the body cavity, measured from the bisector of $\overline{ab}$ to the midpoint of the posterior margin of the aperture (fig. 3, Maj).

Minor Axis (Min) = length of the minor axis of an ellipse approximating the body cavity. This is the distance between the columella and the outer lip measured along the perpendicular bisector of the Major Axis. (fig. 3, Min). Ideally, the Major Axis (Maj) should also be the perpendicular bisector of the minor Axis (Min). For shells in which the aperture is appreciably occluded by previous whorls (fig. 13), the Minor Axis (Min) may be approximated as being twice the perpendicular distance from the midpoint of the Major Axis to the outer lip.

Length of the Siphonal Canal (Lsc) = length of a line segment extending from the midpoint of line segment $\overline{ab}$ to the midpoint of line segment $\overline{cd}$ (fig. 3, Lsc).

Width of the Siphonal Canal (Wsc) = distance between line segments $\overline{ac}$ and $\overline{bd}$ measured along the perpendicular bisector of Lsc (fig. 3, Wsc).

Distance to the Inner Margin (I) = the distance from the axis to the inner margin of the generating curve measured along an extension of the Minor Axis (fig. 3, I). The value of I is positive if the inner and outer margins of the generating curve are on the same side of the axis, and negative if on opposite sides of the axis.

Translation (Y) = the distance along the axis from the apex to a line perpendicular to the axis and passing through the intersection of Maj and Min (fig. 4, Y).

Radius (R) = the perpendicular distance from the axis to the intersection of Maj and Min (fig. 4, R).

$\overline{w_{n-1}w_n}$ = the distance between two adjacent sutures mea-

sured along a radius perpendicular to the shell axis (fig. 5).

Morphometric Parameters

Shape of the Generating Curve (S)

In his first paper on the subject of shell coiling Raup (1961) pointed out that "the shape of the generating curve... is generally irregular enough to greatly hinder mathematical description", and instead used tracings of the outline of the generating curve. Subsequent work was restricted to forms in which the generating curve was circular or roughly elliptical, but mentioned (Raup, 1966) that "the simple parameter S could be subdivided into several parameters, each adding dimensions to four dimensional space." For those forms which have a siphonal canal (i.e. many caenogastropods) the shape of the generating curve of the shell may be better defined in terms of the following four parameters:

Shape of the Generating Curve of the Body Cavity (Sbc)

$$Sbc = Maj / Min$$

This portrays the cross-sectional shape of the body cavity portion of the generating curve as an ellipse.

Shape of the Generating Curve of the Siphonal Canal (Ssc)

$$Ssc = Lsc / Wsc$$

This portrays the cross-sectional shape of the siphonal canal portion of the generating curve as a rectangle.

Relative Siphonal Length (Rsl)

$$Rsl = Lsc / Maj$$

Siphonal Angle (β)

The acute angle between Maj and an extension of Lsc. This angle is considered positive if the siphonal canal is deflected abaxially and negative if deflected adaxially (fig. 3).

Rate of Whorl Expansion (W)

Defined as the rate of increase in the size of the generating curve per revolution (Raup and Michelson, 1965). A convenient method for calculating W has been proposed by Kohn and Riggs (1975).

$$W = \frac{\frac{\overline{w_2w_3}}{\overline{w_1w_2}} + \frac{\overline{w_3w_4}}{\overline{w_2w_3}} + \dots + \frac{\overline{w_{n-1}w_n}}{\overline{w_{n-2}w_{n-1}}}}{n-1}$$

This is the average increase in intersutural distances over $n-1$ whorls. Measurements are usually made in a projected plane perpendicular to the coiling axis, but can also be taken from an apertural view of the shell. This method is not applicable to intact shells which are convoluted (eg. Cypraeidae).

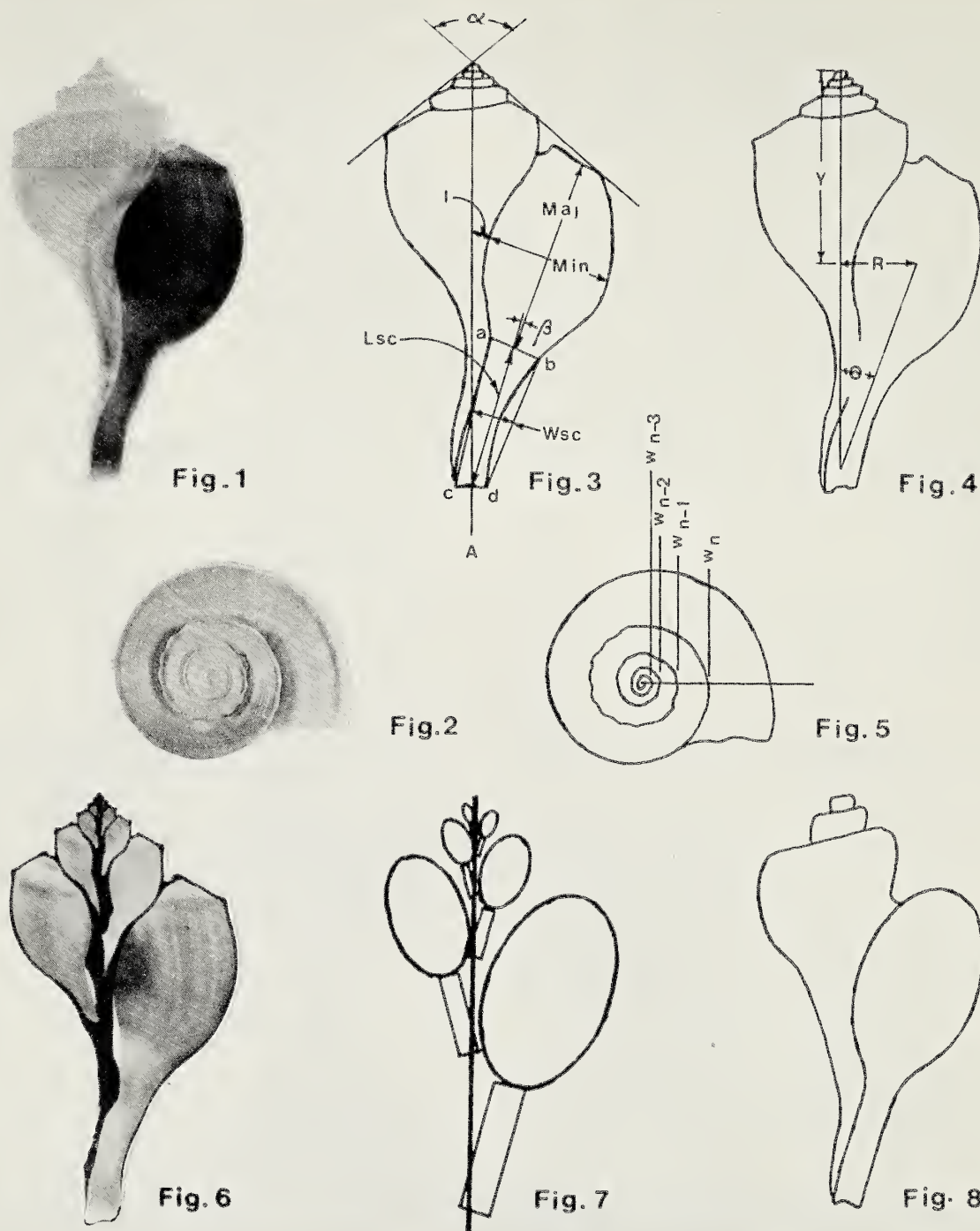
Angle of the Generating Curve (θ)

The acute angle between the coiling axis (A) and Maj (fig. 4).

Position of the Generating Curve Relative to the Axis (D)

$$D = I / (I + Min)$$

Two departures from the original method (Raup, 1967) of determining D should be noted. Firstly, the distances are measured along the Minor Axis (Min) of Sbc rather than perpendicu-



- Fig. 1. Photograph of the apertural aspect of the shell of *Busycotypus canaliculatum* (Linne) (0.5 X).
- Fig. 2. Photograph of the spire aspect of the shell of *B. canaliculatum* (0.5 X).
- Figs. 3-5. Determination of linear and angular measurements of the shell. (for details see text).

- Fig. 6. Photograph of *B. canaliculatum* sectioned through the coiling axis (A) (0.5 X).
- Fig. 7. Computer reconstruction of a cross-section of the shell of *B. canaliculatum* using values from Table I.
- Fig. 8. Shell form drawn from computer reconstruction of *B. canaliculatum*.



Fig. 9



Fig. 10



Fig. 11



Fig. 12



Fig. 13



Fig. 14



Fig. 15

Fig. 9. Photograph of *Conus purpurascens* sectioned through the coiling axis (2.0 X).

Fig. 10. Computer reconstruction of a cross-section of the shell of *C. purpurascens* using values from Table I.

Fig. 11. Photograph of *Colus stimpsoni* sectioned through the coiling axis (1.5 X).

Fig. 12. Computer reconstruction of a cross-section of the shell of *C. stimpsoni* using values from Table I.

Fig. 13.

Photograph of *Conus geographus* sectioned through the coiling axis (1.0 X).

Fig. 14.

Computer reconstruction of a cross-section of the shell of *C. geographus* using values from Table I.

Fig. 15.

Shell form drawn from computer reconstruction of *C. geographus*.

TABLE 1. Values of Morphometric Parameters for the Specimens used in this study.

Species	Sbc	Ssc	Rsl	β	θ	W	D	T
<i>Busycotypus canaliculatum</i> (Linne)	1.64	4.26	0.648	+6.0°	21.0°	1.61	0.132	2.59
<i>Conus purpurascens</i> Sowerby	6.18	0	0	0	15.0°	1.57	0.476	3.25
<i>Colus stimpsoni</i> Morch	1.62	2.90	0.558	+1.0°	19.5°	1.81	0.153	5.68
<i>Conus geographus</i> Linne	2.75	0	0	0	3.0°	1.73	-0.275	5.20

lar to A; Secondly, as the shape of the generating curve of the body cavity (Sbc) is considered to be an ellipse, the inner margin of Sbc might be a hypothetical portion of the curve, rather than the inner margin of the aperture. In certain cases (eg. *Conus geographus* - Table 1) this may result in a negative value for D.

Rate of Whorl Translation (T)

$$T = Y / R$$

Data were taken and applicable parameters calculated for the sample taxa listed in Table 1. Portions of the DELPLOT graphics package (Goodrich, 1980) were used on a Burroughs 7700 computer equipped with a Hewlett-Packard HP 7221A flatbed plotter to produce cross-sectional reconstructions of these taxa (figs. 7, 10, 12, 14). Shell forms were drawn by hand from two of these cross-sections by connecting like points 180° apart (figs. 8, 15).

DISCUSSION

As can be seen from the figures, this modified model produces more realistic reconstructions of actual shells than were formerly possible. An additional benefit is that the values of these parameters can be checked and finely tuned through the use of computer reconstructions. Furthermore, this model is partially compatible with the unmodified version in that, within certain limitations, data are directly comparable.

$S = Sbc$ for forms lacking a siphonal canal ($Ssc = Rsl = \beta = 0$), and in which the aperture is not appreciably occluded by previous whorls. Shells with siphonal canals would give higher S values than expected with Sbc. For shells with irregular or occluded apertures, Sbc assumes a "best fit" ellipse, and would generally yield lower values than S, which measures actual aperture dimensions.

W and T values are directly comparable in both versions of the model.

D values remain comparable when $\theta = 0$, and the aperture is not appreciably occluded by previous whorls. When $\theta \neq 0$, D values could not previously be computed. Kohn and Riggs (1975) used $D = 0$ for several species of *Conus* because the generating curve intersected the coiling axis basally. When the aperture is occluded and D is calculated using a theoretical portion of the generating curve, negative values of D may oc-

casionally be obtained.

It should also be mentioned that the S values used by Vermeij (1971, 1973) are not directly comparable with those of Raup or of this study, but are measured at an angle to the coiling axis. Further complexities in the shape of the generating curve were made use of by Hallers-Tjabbes (1979) in her studies of sexual dimorphism in the shells of *Buccinum undatum*.

A number of additional parameters have been proposed (Kohn and Riggs, 1975), and myriad others are possible for characterizing deviations from this generalized form. Further studies are currently being conducted by the author on the variation and covariation of these and other parameters within the Buccinacea. It is hoped that this paper will stimulate further work on other groups.

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UNIONIDS FROM INDIAN SITES IN McMULLEN AND LIVE OAK COUNTIES, TEXAS

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ABSTRACT

Indian sites, 3400 B.C. to 1200 A.D., in Live Oak and McMullen Counties, Texas yielded 18,000 unionid valves.

Generic and specific determinations were made on 12,000 valves. Seven unionid species were identified all of which occur in the extant fauna of the adjacent Frio River. Two genera, *Truncilla* sp. and *Villosa* sp., were identified which are unrecorded from the drainage system. There were no *Anodonta* identified; however, *Anodonta* are common in the living fauna of the drainage system. Since only 30 specimens had been worked either as tools or jewelry and since most specimens were

broken at the posterior 1/2 to 1/3 of the valve, it is judged the unionids were used primarily for food.

In August 1981, Choke Creek Canyon Dam impounded water of the Frio River, a tributary of the Nueces River of south Texas. The dam is located approximately 4.5 km west of Three Rivers, Live Oak County, Texas. The water inundated the Frio River valley in the western one-half of Live Oak and eastern one-half of McMullen counties. This area was extensively used by American Indians.

The Archeological Center of the University of Texas at San Antonio established 165 excavation sites and test pits in the areas to be inundated and forwarded all unionids to me for identification and interpretation. The sites were dated for Indian activity ranging from 3400 B.C. to 1200 A.D. Test pits, 1m², were exposed to a depth of 90 cm marking strata at 10 cm increments to determine desirability for complete excavation. Unionids were recovered from some test pits which were not excavated for a lack of sufficient evidence of human activity. Excavated sites were marked into 1m² grids which were exposed to record all material into strata at either 5 or 10 cm intervals.

Most of the 18,000 valves examined were fragments; however, sufficient hinge plates were preserved to permit identification of about 12,000 valves to either genus or species. Identification was aided by comparing the fragments to the extant unionid fauna of the Frio River, to the unionid fauna of the lower Nueces River (Murray, 1978), and to the unionid records of the river system (Strecker, 1931).

Following is a list of species showing numbers of valves from all excavations minus test pits: 215 *Lampsilis anodontoides* (Lea); 5,452 *Cyrtonebias tampicoensis* (Lea); 190 *Toxolasma* (= *Carunculina*) *parvus* (Barnes); 38 *Amblema plicata costata* (Say); 1 *Quadrula aurea* (Lea); 3 *Leptodea fragilis* (Rafinesque); and 32 *Megaloniaias nervosa* (= *gigantea*) (Rafinesque).

Approximately 2,500 valve fragments were identified to genus. Following is a list of genera giving the numbers of valves identified from all excavated sites minus test pits: 2,488 *Lampsilis* sp.; 13 *Amblema* sp.; 17 *Quadrula* sp.; 2 *Leptodea* sp. Because these hinge fragments were too small for positive identification and because other species of these genera have been recorded from the river system, generic identification only was made.

Two valves of *Truncilla* sp. were identified. This genus has not been recorded in this river system. The southernmost record

for *Truncilla* in Texas is the Colorado River system, approximately 128 km north of the Nueces River system (Strecker, 1931). *Truncilla* may have been carried into this area from another drainage system, or *Truncilla* may have lived in this drainage system at an earlier date. Three valves of *Villosa* sp. were initially identified. Because the valves identified as *Villosa* were highly worn, they might be *Toxolasma parvus*. The closest record of *Villosa* to the Nueces River drainage is the Trinity River (Strecker, 1931), approximately 320 km east of these Indian sites. Distributional records of *Truncilla*, *Villosa*, and other unionids in Texas are inadequately known due to a sparsity of careful surveys of Texas rivers.

The complete absence of *Anodonta* spp. is noteworthy. Both *A. grandis* and *A. imbecilis* occur in the river system and in the Frio River adjacent to the sites. The fragile shells of *Anodonta* may have been fragmented so that they were unrecognizable but present; however, the occurrence of other fragile shells (*Leptodea fragilis* and *Toxolasma parvus*) indicates that *Anodonta* spp. should have been preserved if present. Since 12,000 valves were identified, I judge that sufficient specimens were examined to conclude that *Anodonta* spp. were not in the samples. *Anodonta* spp. may have had an unpleasant taste and not collected by the Indians; however, this implies that each group of inhabitants over a 4,600 year period had prior knowledge of a taste preference against *Anodonta* spp. Based on this study, it is my opinion that *Anodonta* spp. were not a part of the Nueces River system until some date later than 1200 A.D.

Because few valves (25-30) showed evidence of being worked for jewelry or tools and because large specimens were broken at the posterior 1/3 of the valve, it is judged that the unionids were used primarily as a source of food. *Cyrtonebias tampicoensis* and *Lampsilis* spp. account for 8,155 valves of the 8,424 valves removed from excavated sites (test pits not included). The large numbers of *C. tampicoensis* and *Lampsilis* spp. in comparison to other species recovered probably reflect the population levels of these species at the time of collection. This relationship of population sizes occurs in the extant fauna of the Frio River adjacent to the excavated sites.

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A SURVEY OF THE NAIADES OF THE OHOOPEE RIVER, GEORGIA

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ABSTRACT

The Ohoopsee River is a small tributary of the Altamaha River. The naiad fauna of the river was sampled at fifty-three sites from 1975 through 1981. Seventeen species and *Corbicula* were found. All the endemic naiad species recorded from the Altamaha River were found living in the Ohoopsee River. The naiad populations of the upper, middle and lower regions of the river are somewhat distinct. There appears to be several undefined barriers which limit the distribution of several of the

species to upper or lower regions of the Ohoopsee River system. The naiad populations of the Ohoopsee River system appear to be in good shape. The Ohoopsee River may serve as a refuge for the preservation of the endemic species, if the Altamaha River populations continue to decline.

INTRODUCTION

The Ohoopsee River is the principal tributary of the Altamaha River proper.

It originates in Washington County, Georgia and flows 201 km. southeast to the Altamaha river in Tattnall County. This river flows almost entirely on the Vidalia Upland of the lower Coastal Plain physiographic province (Smith and Green, 1968).

The Ohoopsee system drains approximately 3317 square kilometers (Hall and Hall, 1921). The river is small with a discharge of about 700 cubic feet/second during average summer conditions (EPD, 1972). This about 7% of the total volume of the Altamaha River (May, 1974).

The floodplain of the Ohoopsee River, for most of its length, is dominated by cypress swamps, gum-cypress swamps and bottomland hardwoods (Wharton, 1978). The waters are highly colored, slightly acid (pH 6.5) with a low turbidity, nutrient level and B.O.D.5. The water is well oxygenated (EPD, 1978). The predominant bottom substrate is sand which varies from fine to coarse to even gravel in some places. There are a few areas where there are out-croppings of consolidated sediments such as claystone and sandstone.

The river system is currently used by several towns, the Georgia State Prison at Reidsville and a few small businesses for the discharge of secondarily treated wastewater (EPD, 1978). The Ohoopsee River is a popular place for fishing, swimming and canoeing.

A number of collections have been made from the Ohoopsee River in the past. Johnson (1970) gives distribution records for ten species from twenty-one different sites. Most of these records are from the headwaters. The naiad fauna was very poorly known. The principle objective of this study was to document, in some detail, the distribution of the naiades in the Ohoopsee River system.

METHODS

Most naiades were collected by hand picking in shallow water. A rake was used in deeper waters where the substrate was sand. At a few localities where there were deep holes, naiades were collected by skin-diving. Some of the material collected was deposited in the Ohio State University Museum of Zoology. Small samples were processed and put in a small collection at Brunswick Junior College. The remainder of the material was processed and catalogued in the collections of the author. Most of the names used herein are those used by Dr. David H. Stansbery and The Ohio State University Museum of Zoology.

Fifty-three sites were examined for naiades (Table 1). Thirty-seven of the sites examined were on the Ohoopsee River itself, the other sites were on the small tributaries. Most of the sites are situated at bridges and boat ramps. A small jon boat was used to explore the lower section of the Ohoopsee River from the U.S. Rt. 56 bridge (site 21) downstream to its confluence with the Altamaha River.

RESULTS

Seventeen species of freshwater naiades and *Corbicula leana* Prime, 1864 were found at fifty-three sites in the Ohoopsee River system (Table 2). Johnson (1970) records ten species of naiades from the Ohoopsee River system. Dr. Stansbery has identified some specimens taken from Battleground Creek and the Little Ohoopsee River as being *Uniomerus declivis* (Say, 1831). *Uniomerus declivis* has not been previously recorded from the Altamaha River system. *Anodonta gibbosa* (Say, 1824), *Elliptio shepardiana* (Lea, 1834), *Canthyria spinosa* (Lea, 1836), *Toxolasma pullus* (Conrad, 1838), *Lampsilis dolabraeformis* (Lea, 1838) and *Lampsilis splendida* (Lea, 1838) are reported herein for the first time as occurring in the Ohoopsee River. All the naiad species which Johnson (1970) recorded from the Altamaha River system have been found in

the Ohoopsee River system with two exceptions. *Anodonta couperiana* (Lea, 1842), and *Anodonta cataracta* (Say, 1817) were not collected in the Ohoopsee River system.

The naiad fauna characteristic of the headwaters (Sites 28 - 42 and sites 48 - 51) include *Uniomerus obesus* (Lea, 1831), *Elliptio icterina* (Conrad, 1834), *Elliptio complanata* (Lightfoot, 1786), *Elliptio fisheriana* (Lea, 1838) and *Villosa vibex* (Conrad, 1834). All these species, except *E. fisheriana* are common at numerous sites. None of these species are endemic to the Altamaha River system. The distribution records for the headwater species are very incomplete. Most of the small tributaries have not been examined thoroughly and collections are spotty.

The naiad fauna characteristic of the lower Ohoopsee River (sites 1 - 18) include *Elliptio hopetonensis* (Lea, 1838), *Elliptio dariensis* (Lea, 1842), *Elliptio shepardiana* (Lea, 1834), *Canthyria spinosa* (Lea, 1836), *Lampsilis splendida* (Lea, 1838), *Lampsilis dolabraeformis* (Lea, 1838), *Toxolasma pullus* (Conrad, 1838) and *Alasmidonta arcuata* (Lea, 1838). All these species except *L. splendida* and *T. pullus* are endemic to the Altamaha River system.

The most common naiad in the lower Ohoopsee River is *E. hopetonensis*. This species is common along the steep banks, in the deeper holes and backwaters of large sand banks. The most obvious naiad in the Ohoopsee River at sites 1 - 18 is *L. dolabraeformis*. This species is common along the sides and tail waters of the sand banks, in the runs and shifting sands of sand bars. At certain times of the year it can be found almost anywhere. *L. dolabraeformis* moves around alot and leaves conspicuous trails which make it easy to locate them. *Canthyria spinosa* is most commonly found in stable sand runs along sand banks. It appears to be clumped in thinly scattered beds. The distribution of *C. spinosa* is limited to the lower Ohoopsee River. This is the first naiad species to disappear as one moves upstream. The species abruptly stops at a site below Thomas Creek. It is conspicuously absent from otherwise ideal habitats further upstream. This may be due to its fish host, whatever that is. *Elliptio shepardiana* is also found along stable banks with *E. hopetonensis*, *E. dariensis* and *L. splendida*. *E. shepardiana* is usually not found in large numbers, but fairly consistently up through site 14, above which it disappears. It then reappears in two sites on Rocky Creek. *Elliptio dariensis* has the widest distribution of any of the species in the Ohoopsee River. This species is not as common as *E. hopetonensis* in most areas. *Lampsilis splendida* has a distribution very similar to *E. shepardiana*. Both species are found living together, but *L. splendida* seems to prefer banks with more silty deposits and they are usually in shallower water. *Toxolasma pullus* is most often found along fine sand beaches in very shallow water. It is frequently associated with *Villosa ogecheensis* (Conrad, 1849). *Toxolasma pullus* has a distribution almost identical to that of *L. dolabraeformis*. *Alasmidonta arcuata* (Lea, 1838) has always been one of the rarer endemic species in the Altamaha River. In the Ohoopsee River *Alasmidonta arcuata* has not been found in large numbers, but it is not rare. A specimen or two can usually be found by looking in the decomposing organic debris in sheltered areas. *Alasmidonta arcuata* has a fairly extensive distribution in the Ohoopsee River.

The naiades which are characteristic of the middle region of the Ohoopsee River (sites 19 - 27) are *E. hopetonensis*, *E. dariensis*, and *A. arcuata*. This middle region of the Ohoopsee River has the lowest naiad diversity.

Villosa ogecheensis (Conrad, 1849) is usually found along the shore of a sandy beach or a ponded backwater area of the

river. *V. ogeecheensis* is somewhat more common in the headwaters, however, it does not appear to be characteristic of any particular region of the river. *Anodonta imbecillis* (Say, 1829) has a very sporadic distribution. This species is usually collected on soft muddy substrates. These substrates are not very common in the Ohoopsee River. *Anodonta gibbosa* (Say, 1824) has been found only at one site in the lower region of the Ohoopsee River. It also prefers a soft muddy substrate.

The distribution of the Genus *Elliptio* in the Ohoopsee River

system is particularly interesting. There is an overlap of the lower and middle river species with the headwater species. Four or five species of *Elliptio* have been found in two areas of the system, sites 28 - 36 of the Ohoopsee River and site 48 of the Little Ohoopsee River.

Specimens in the Genus *Elliptio*, which were collected in Rocky Creek, offer another interesting question. *Elliptio shepardiana* is present in this small creek quite isolated from the mainstream population. This species occurs with what appears

Table 1 Collecting Sites, Ohoopsee River System
1975 - 1981

Sites	Location
	<i>Ohoopsee River</i>
1	Tattnall County, Tattnall County boat ramp, 2.1 km. south of Ga. Rt. 178 bridge
2	Tattnall County, mouth of Ohoopsee River, 2.1 km. south of Ga. Rt. 178 bridge
3	Tattnall County, 1.6 km. south of Ga. Rt. 178 bridge
4	Tattnall County, 0.5 km. south of Ga. Rt. 178 bridge
5	Tattnall County, Ga. Rt. 178 bridge, 7.4 km. west of Five Points
6	Tattnall County, 1.3 km. NNW of Ga. Rt. 178 bridge
7	Tattnall County, 3.7 km. NNW of Ga. Rt. 178 bridge
8	Tattnall County, 5.7 km. NNW of Ga. Rt. 178 bridge
9	Tattnall County, 2.9 km. SE of Ga. Rt. 147 bridge
10	Tattnall County, 2.8 km. SE of Ga. Rt. 147 bridge
11	Tattnall County, 2.6 km. SE of Ga. Rt. 147 bridge
12	Tattnall County, 1.2 km. SE of Ga. Rt. 147 bridge
13	Tattnall County, 0.3 km. SE of Ga. Rt. 147 bridge
14	Tattnall County, Ga. Rt. 147 bridge, 8.7 km. south of Reidsville
15	Tattnall County, 1.8 km. NNW of Ga. Rt. 147 bridge
16	Tattnall County, 2.8 km. NNW of Ga. Rt. 147 bridge
17	Tattnall County, 3.0 km. NNW of Ga. Rt. 147 bridge
18	Tattnall County, 3.8 km. NNW of Ga. Rt. 147 bridge
19	Tattnall County, at the mouth of Rocky Creek, 4.8 km. NNW of Ga. Rt. 147 bridge
20	Tattnall County, Tattnall County boat ramp, 1.6 km. SSE of Ga. Rt. 56 bridge
21	Tattnall County, Ga. Rt. 56 bridge, 5.2 km. west of Reidsville
22	Tattnall County, U.S. Rt. 280 bridge, 7.4 km. NW of Reidsville
23	Tattnall/Toombs Counties, Ga. Rt. 292 bridge, 12.1 km. east of Lyons
24	Tattnall/Toombs Counties, Ga. Rt. 152 bridge, 12.9 km. NNE of Lyons
25	Emanuel/Chandler Counties, county road bridge, 4.7 km. NE of Ga. Rt. 86, 17.7 km. NNE of Lyons
26	Emanuel County, U.S. Rt. 1/Ga. Rt. 46 bridge, 4 km. NNE of Oak Park
27	Treutlen/Emanuel Counties, Ga. Rt. 297 bridge, 6.6 km. SSW of Nunez
28	Treutlen/Emanuel Counties, Ga. Rt. 56 bridge, 3.1 km. south of Cavena
29	Treutlen/Emanuel Counties, U.S. Rt./Ga. Rt. 171 bridge, 9.8 km. ENE of Adrian
30	Johnson/Emanuel Counties, U.S. Rt. 80 bridge, 1.9 km. NNE of Adrian
31	Johnson County, county road bridge, 0.8 km. NE of Ga. Rt. 78, 9.7 km. north of Adrian
32	Johnson County, county road bridge, 0.8 km. NE of Ga. Rt. 78, 15.6 km. north of Adrian
33	Johnson County, Ga. Rt. 78 bridge, 6.0 km. south of Wrightsville
34	Johnson County, U.S. 319/Ga. Rt. 15 bridge, 3.9 km. SW of Wrightsville
35	Johnson County, Ga. Rt. 57 bridge, 4.8 km. west of Wrightsville
36	Washington County, county road bridge, 7.6 km. WSW of Harrison, 12.2 km. NNW of Wrightsville
37	Washington County, Ga. Rt. 15 bridge, 6 km. SSE of Tennille
	<i>Rocky Creek</i>
38	Tattnall County, near the confluence with the Ohoopsee River, 4.8 km. NNW of Ga. Rt. 147 bridge, 6.5 km. SW of Reidsville
39	Toombs County, county road bridge, 7.7 km. SW of Reidsville
40	Toombs County, Ga. Rt. 178 bridge, 12.6 km. SW of Reidsville
41	Toombs County, county road bridge, 1.8 km. SE of Ga. Rt. 56, 3.6 km. SSW of New Branch
42	Toombs County, Ga. Rt. 56 bridge, 1.9 km. ENE of Johnson Corner
	<i>Pendleton Creek</i>
43	Toombs County, Ga. Rt. 86 bridge, 3.2 km. S. of Ohoopsee
44	Toombs County, Ga. Rt. 292 bridge, 5.8 km. ESE of Lyons
45	Treutlen County, Ga. Rt. 15/78 bridge, 11.8 km. north of Soperton
46	Toombs County, U.S. Rt. 1 bridge, 2.7 km. north of Lyons
	<i>Mulepen Creek</i>
47	Emanuel County, U.S. Rt. 80 bridge, 6.3 km. ENE of Adrian
	<i>Little Ohoopsee River</i>
48	Emanuel County, Ga. Rt. 56 bridge, 2.4 km. NE of Cavena
49	Emanuel County, U.S. Rt. 80 bridge, 11.8 km. ENE of Adrian
50	Johnson County, Ga. Rt. 57 bridge, at Kite, 19.2 km. NW of Swainsboro
51	Johnson County, U.S. Rt. 319/Ga. Rt. 78 bridge, 12.1 km. NNW of Kite
	<i>Yam Grandy Creek</i>
52	Emanuel County, Ga. Rt. 56 bridge, 6.7 km. SW of Swainsboro
53	Johnson County, U.S. Rt. 221/Ga. Rt. 171 bridge, 1.1 km. north of Kite

to be another species of lanceolate *Elliptio*. This unknown *Elliptio* species possesses shell characters which are intermediate between *E. fisheriana* of the headwaters and *E. shepardiana*.

CONCLUSIONS

The naiad populations in the Altamaha River appear to be greatly reduced at the present time. Many areas have not been adequately investigated, but the preliminary investigations are not encouraging. Immatures are rarely found and seemingly ideal habitats are devoid of any naiad species. In the Ohoopsee River, immatures of all species are found on a regular basis. Even though several species have a limited range in the Ohoopsee River, they are found at several localities within their range. The apparent rarity of some species should not be interpreted in a negative way. Some species have always been rather rare and others are simply small and hard to find. Ideal habitat for naiades in the Genus *Anodonta* are limited in the Ohoopsee River. At the present time the naiad populations of the Ohoopsee River system are in excellent condition. If the naiad populations in the Altamaha River continue to decline, then the Ohoopsee River may be an important refuge for the preservation of these endemic Altamaha River species.

ACKNOWLEDGEMENT

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TRAWL COLLECTIONS OF *MACOMA CONSTRICTA* AND *SPISULA RAVENELI* (BIVALVIA: TELLINIDAE AND MACTRIDAE) IN VICINITY OF CAPE FEAR RIVER, NC AND THEIR RELATIONSHIP TO PERIODS OF ENVIRONMENTAL STRESS.

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ABSTRACT

Systematic weekly otter trawling within the lower Cape Fear River and adjacent Atlantic Ocean during years 1973-1980 yielded occasional collections of *Macoma constricta* shell with partial periostracal coverings in 1974, 1977, and 1978, and live *Spisula raveneli* in 1977. We suggest that the major collections of *M. constricta* were the result of abnormal stream scouring, caused by Hurricane "Agnes", of a substrate containing a once viable population. Unusually low water temperatures and salinities acting together during the 1976-1977 winter may have contributed to collections of *S. raveneli* by affecting their substrate burrowing ability and thus causing them to be more vulnerable to trawl collection. Preliminary data are presented suggesting that the height/length ratio of *S. raveneli* is significantly larger than that of *S. solidissima*.

INTRODUCTION

Collections of *Macoma constricta* (Bruguiere, 1792) shells (Fig. 1) and living *Spisula* sp. (Fig. 2) were obtained during a six year (1973-1978) intensive environmental trawl survey and study of Cape Fear River estuary by the junior author. The sporadic nature of these collections was believed the result of

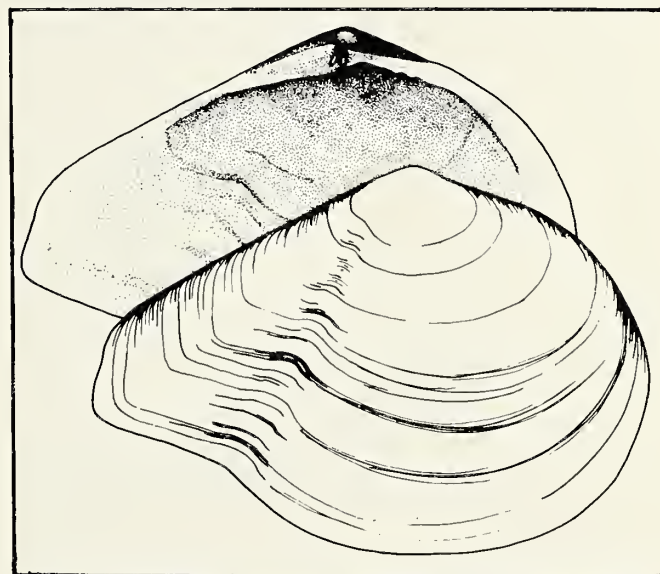


Figure 1. *Macoma constricta* (Bruguiere, 1927). Length = 60 mm (2.4 in.).

environmental stresses affecting nearby living populations of these species. This paper examines these speculations and discusses the identity of the *Spisula* sp.

All specimens were collected by a 12.5/15.3 m semiballon otter trawl of 31.3 mm stretched No. 15 nylon stretched-mesh construction and were presumed to have been epifaunal. Twenty-one stations were sampled within the area (total samples = 10646); however, the single ocean station was usually sampled at four or more offshore depths. Sample stations

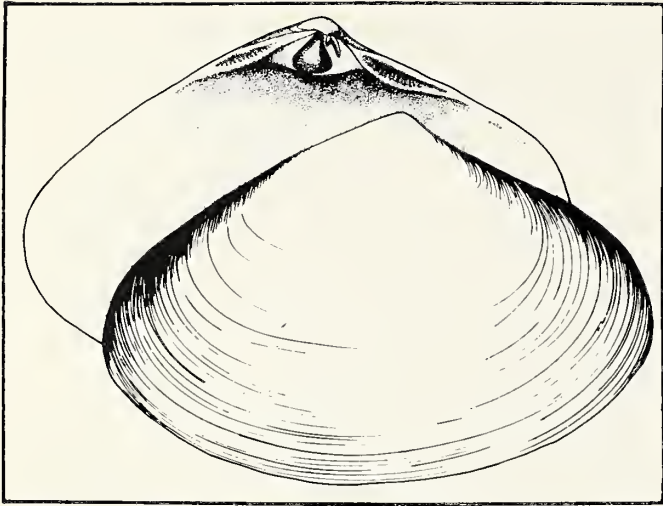


Figure 2. *Spisula raveneli* (Conrad, 1831). Length = 55 mm (2.2 in.).

were established the length of the Cape Fear estuary to sample deep channel and shallow waters. Sampling consisted of 3-4 days effort per week at each station for 31 weeks during the year. At each station, at least one sample was taken per day during the 3-4 day period. Each trawl sample covered approximately 0.25 km² of area (see Schwartz et al., 1979a,b for more detailed sampling, location, and environmental information) (Fig. 3 & 4). Frequency of station sampling that yielded *M. constricta* and *Spisula* sp. and number of specimens collected is illustrated by year in Fig. 4 and Table 1. Collected specimens were accessioned into the mollusk collection of the University of North Carolina, Institute of Marine Sciences (UNC-IMS). Height/length ratios were analyzed using the method of Hubbs and Hubbs (1953) (Fig. 5). Correlation coefficient analysis was used to test height/length ratio vs. shell length values.

Macoma constricta (Burguiere) (Fig. 1).

No live specimens of *Macoma constricta* were collected. Many shells had a partial periostracal covering and few possessed a ligament. These shells resembled large shells of *Macoma balthica* (Linne, 1758) from North Carolina estuaries containing living *M. balthica* populations; thus, the *M. constricta* shells were believed to be of or from a nearby viable population. Most *M. constricta* first appeared in 1974 during March and May in the lower Cape Fear River near stations #18 and 19. Collections of a few specimens occurred October, 1977 and February, 1978 at the same general locations and in February, 1978 at the ocean station (#OC).

Salinities and water temperatures at stations #18 and 19 during 1973-1977 (Tables 2 and 3), which ranged 11-31‰ and 5-32°C, were not suggestive of a low salinity or temperature-related mortality of *M. constricta*. Winter water temperatures noted in January-March, 1974 actually were higher than in most other sampled years. A high river runoff in August, 1973 (caused by hurricane "Agnes") produced the highest runoff recorded in the Cape Fear River in 26 years (Schwartz, et al., 1979a). The resultant runoff may have scoured substrate areas near stations #18 and 19 and in doing so dug out contained *M. constricta* specimens. No short term low salinities were recorded at stations #18 and 19 following the hurricane in August (Table 2). The sparse collections of *M. constricta* in 1977-1978 (Fig. 4 and Table 1) were not considered large enough to suggest addi-

tional environmental disruptions.

Published literature concerning this species is meager. Dall (1900) lists it as Recent occurring from the coast of New Jersey south to Brazil. There are no known North Carolina records of living specimens. Holmes (1860) recorded living specimens in South Carolina in brackish water near the mouth of the Santee River. Other living records, all from the Gulf of Mexico (Louisiana, Texas, and Mexico) have been recorded by Andrews (1971), Behre (1950), Ekdale (1974), Mitchell (1894), and Pulley (1951). Andrews (1971) does state that the species in Texas is more tolerant of salinity and temperature extremes than other Texas *Macoma*.

The reliability of periostracum and ligament presence in bivalves as an indication of recent living specimens was discussed with Dr. Joseph G. Carter (University of North Carolina at Chapel Hill, Geology Department, pers. comm.). Dr. Carter believes that in clay-type sediments (typical of stations 18 and 19, Schwartz 1979a,b) such bivalve characteristics may last as long as 5000 years before disintegration.

Thus we suggest that the only environmental stress noted prior to the collection of *M. constricta* in the Cape Fear River



Figure 3. Cape Fear, NC sampling region. Dots represent river sampling stations; shaded regions represent areas covered when stations #18, 19, and OS (Ocean Station) were sampled; "...." represents the "rocks", a rock jetty built in the early 1800's to close off upper inlet of Cape Fear River.

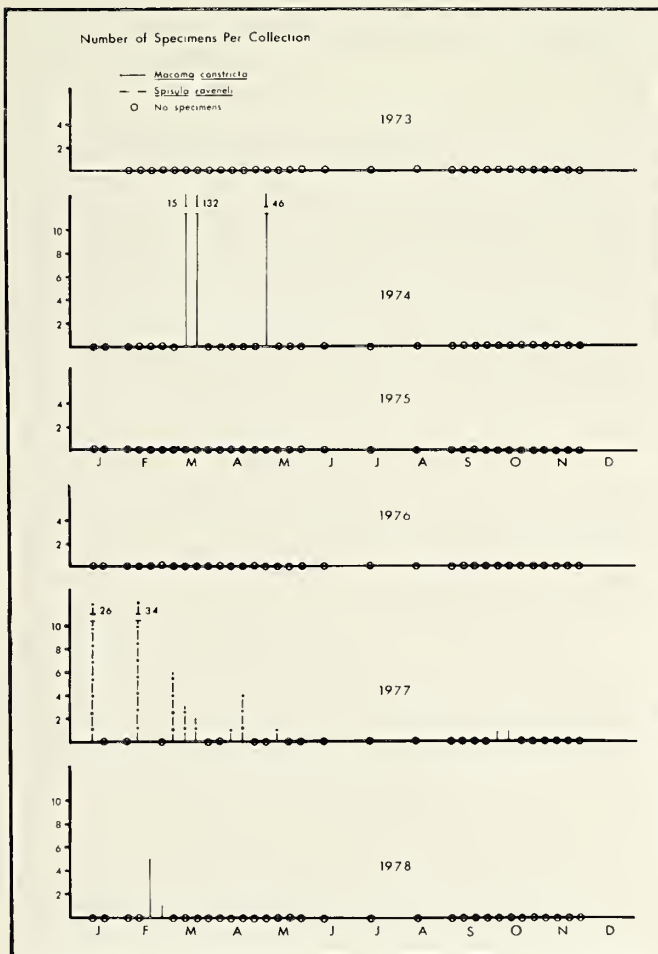


Figure 4. Sampling frequency (o) and numbers (vertical lines) of *Macoma constricta* and *Spisula* sp. collected 1973-1978 at stations #18, 19, and OS (Fig. 3) (data lumped by week); months identified by single letter abbreviations. See Table 1 for additional effort and collection data.

system was the high runoff in 1973. Collections in 1974 may have been facilitated by this abnormal stream scouring of a nearby substrate containing a *M. constricta* population of recent geological history but of unknown existence. We also submit that the construction of the "rocks", a man made barrier across the old Cape Fear outlet, and subsequent deepening of the river to the seas at Southport, in the 1800's (note Fig. 3) dramatically affected river discharge and probably caused considerable ecological changes in that area, an area which may have had a viable *M. constricta* population prior to the late 1800's.

Spisula raveneli (Conrad) (Fig. 2).

Spisula sp. was collected during the extensive six year sampling program only from January through May 1977 (Fig. 4 and Table 1). Most specimens were alive and from the ocean station.

Collected specimens of the *Spisula* sp. were evaluated in order to determine whether they were juvenile *S. solidissima* (Dillwyn, 1817) [syn. = *S. solidissima similis* (Say, 1822)] or *S. raveneli*. Abbott (1974) suggests that *S. raveneli* is a synonym of

S. s. similis and that both *S. solidissima* and *S. s. similis* occur within North Carolina waters. The convention of Ropes (1980) and Jacobson and Old (1966) in treating *S. raveneli* as a species and not as a subspecies of *S. solidissima* was followed. Emerson and Jacobson (1976) state that *S. s. raveneli* is smaller, "proportionately, lower, more elongate and smoother" than *S. solidissima*.

Height/length ratios were determined for all *Spisula* sp. specimens collected from the Cape Fear region during the survey in 1977. Similar ratios were also determined for specimens from earlier collections of *S. solidissima* (collected between Nova Scotia and North Carolina) and *S. raveneli* (collected between South Carolina and Florida) catalogued in the UNC-IMS mollusk collection. Definition of shell height and shell length was as illustrated in Abbott (1974, p. 11). Mean height/length ratio for the *Spisula* sp. data is 1.44, for *S. solidissima* is 1.31, and for *S. raveneli* is 1.45 respectively. Using the Hubbs and Hubbs (1953) technique (Fig. 5), mean ratio values for *Spisula* sp. and *S. raveneli* were determined to be significantly similar and both significantly larger than the mean ratio value of the *S. solidissima* data.

The relationship of length vs., the height/length ratio for data of all three forms was also determined. Correlation coefficient values were: *Spisula* sp., $r = 0.170$ ($N=74$); *S. solidissima*, $r = 0.443$ ($N=34$); *S. raveneli*, $r = 0.205$ ($N=30$). No significant relationship of height/length ratio to length is indicated (1% level) by this data. Note, that the greater the ratio value, the lower the shell proportionality. Thus the results indicate that *Spisula* sp. and *S. raveneli* had a significantly lower shell proportionality than did the examined *S. solidissima*. The data further indicate that the *Spisula* sp. specimens collected from the Cape Fear region were not *S. solidissima* but *S. raveneli*.

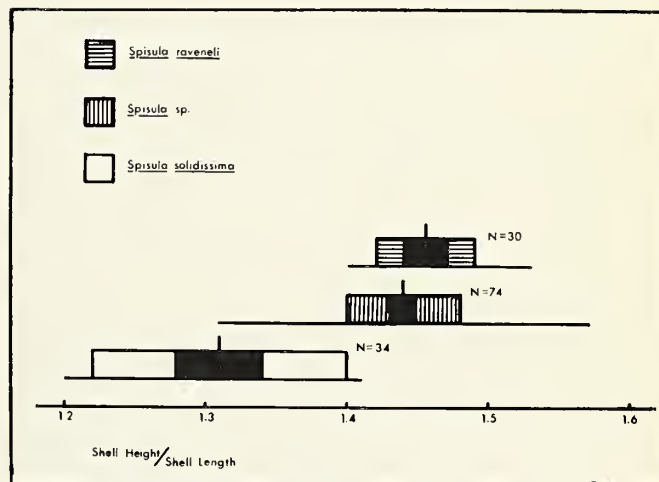


Figure 5. Comparison of shell height/shell length ratio data from *Spisula raveneli*, *Spisula* sp., and *S. solidissima*. Block diagrams adapted from Hubbs & Hubbs (1953): Horizontal lines = range of data; vertical line = mean of data; hollow blocks = range of $\pm$ one standard deviation about the mean; solid blocks = range of $\pm$ two standard errors about the mean. It is stated that considerable reliance can be placed on the significance between samples, if the solid blocks are slightly separated or do not overlap by more than 33% of the smaller solid block.

A weakened ability by many marine invertebrates to withstand lowered salinities during decreasing temperatures is common knowledge (Moore, 1958). However, among mollusca, this phenomenon has not been well documented by way of experimental evidence. Ocean salinities and temperatures during September 1976 through March 1977 were generally lower than in other seasons (Table 4) and may have prevented existing ocean station *Spisula* from remaining burrowed in the substrate during this period and thereby increasing their vulnerability to trawl capture. Ropes (1980) showed that burrowing activity in small *S. solidissima* is decreased under cold conditions.

Minimum lengths and heights of collected specimens were 31 and 23 mm respectively. As stretched bar size of the net was 31.3 mm, specimens smaller and/or younger may have been washed through the net during or before collection periods. Growth ring analysis through total daily ring counts, believed to be daily-formed rings, of two of the January collected speci-

mens, using an acetate peel technique (see Kennish et al., 1980; Ropes and O'Brien, 1979) suggests that the collected population may have been 1¼-1½ years old; 460-480 rings were present.

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TABLE 1. EFFORT AT TRAWL STATIONS THAT YIELDED MOLLUSKS BY YEAR. "Effort" = number of samples taken; "Stat. *M. con.*" = number of samples containing *Macoma constricta*; "Stat. *Spis.*" = number of samples containing *Spisula* sp.; "Catch *M. con.*" = total number of *M. constricta* caught; "Catch *Spis.*" = total number of *Spisula* sp. caught.

TRAWL STATION	YEAR						
	1973	1974	1975	1976	1977	1978	TOTAL
#18 Effort	67	58	79	82	90	82	445
Stat. <i>M. con.</i>	0	1	0	0	1	0	2
Stat. <i>Spis.</i>	0	0	0	0	2	0	2
Catch <i>M. con.</i>	0	46	0	0	1	0	47
Catch <i>Spis.</i>	0	0	0	0	3	0	3
#19 Effort	73	51	74	82	84	74	438
Stat. <i>M. con.</i>	0	2	0	0	1	1	4
Stat. <i>Spis.</i>	0	0	0	0	1	0	1
Catch <i>M. con.</i>	0	147	0	0	1	1	149
Catch <i>Spis.</i>	0	0	0	0	3	0	3
#00C Effort	251	240	332	269	269	211	1572
Stat. <i>M. con.</i>	0	0	0	0	0	1	1
Stat. <i>Spis.</i>	0	0	0	0	6	0	6
Catch <i>M. con.</i>	0	0	0	0	0	5	5
Catch <i>Spis.</i>	0	0	0	0	71	0	71

TABLE 2. MEAN SALINITY (‰) per STATION per MONTH

Year	Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
1973	18	--	23	23	20	18	--	23	27	25	30	28	--	23.0
	19	--	22	24	16	18	--	21	26	26	27	29	--	22.2
1974	18	--	23	21	23	23	25	28	17	25	29	29	--	25.8
	19	25	23	20	11	22	23	26	14	23	28	29	--	23.7
1975	18	19	14	14	22	21	22	21	25	25	27	27	--	22.7
	19	20	13	14	20	23	22	21	24	24	27	27	--	22.2
1976	18	18	22	21	25	26	25	16	27	28	27	26	--	25.0
	19	17	18	18	24	26	18	13	23	27	26	25	--	22.4
1977	18	15	22	19	23	28	26	29	28	27	29	23	--	24.6
	19	16	22	18	16	27	26	29	31	25	27	24	--	23.3
1978	18	27	27	19	25	18	29	20	21	27	30	27	--	23.7
	19	26	27	23	26	18	25	25	22	24	29	33	--	24.7

TABLE 3. MEAN TEMPERATURE (°C) per STATION per MONTH

Year	Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
1973	18	--	8	15	17	21	--	27	28	27	21	15	19	19.2
	19	--	7	15	17	22	--	27	28	27	21	15	20	19.5
1974	18	--	12	15	19	23	27	27	26	26	21	19	--	21.7
	19	13	11	16	19	24	27	28	26	26	21	20	--	21.9
1975	18	10	13	12	17	25	28	27	28	26	24	22	--	21.3
	19	10	13	13	17	25	28	27	29	26	23	23	--	21.4
1976	18	11	14	18	20	22	25	27	28	25	20	13	--	19.6
	19	11	14	18	20	22	26	27	27	25	20	13	--	19.8
1977	18	6	9	14	14	21	25	31	28	27	20	18	--	18.6
	19	5	9	13	19	22	25	32	28	27	20	18	--	19.3
1978	18	8	7	11	17	19	25	30	29	28	20	17	--	22.1
	19	8	6	11	17	19	26	25	29	27	20	17	--	17.2

TABLE 4. MEAN TEMPERATURE and SALINITY DATA per MONTH - OCEAN STATION*

TEMPERATURES (°C)														
Year	Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
1973	18	--	9	15	16	20	--	27	28	27	21	16	16	18.0
	19	--	11	14	18	23	26	28	26	26	23	20	--	20.9
1974	18	10	12	12	15	23	27	27	28	26	23	22	--	21.3
	19	9	13	17	19	22	23	27	28	25	21	13	--	19.6
1975	18	6	8	13	19	21	25	31	29	27	21	19	--	18.0
	19	9	7	11	16	19	28	27	28	28	22	17	--	17.2
SALINITIES (‰)														
1973	18	--	30	29	27	28	--	30	29	32	31	31	--	29.4
	19	--	29	30	26	31	34	34	30	33	34	35	--	31.0
1974	18	31	31	28	31	32	32	25	30	33	33	33	--	29.4
	19	30	26	29	31	31	32	27	25	31	25	30	--	29.2
1975	18	27	27	25	27	31	38	30	33	31	30	34	--	29.2
	19	33	34	32	32	31	33	33	29	27	33	34	--	32.2

* BOLD FACE TYPE SUGGESTS UNUSUALLY LOW ENVIRONMENTAL CONDITIONS

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EFFECTS OF 2,4-D TREATMENT ON GROWTH AND SURVIVAL OF FINGERNAIL CLAMS (BIVALVIA: PISIDIIDAE) IN ARTIFICIAL POND ECOSYSTEMS

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ABSTRACT

Growth of fingernail clams in artificial ponds was inhibited immediately after treatment with either 2,4-D DMA or 2,4-D BEE in concentrations of 1 mg/l in the water column. Growth in treated ponds resumed after 9-15 days. After 46 days growth exceeded that in controls. One mg 2,4-D/l caused no significant mortality. Survival in treated ponds was secondarily enhanced after 50-65 days.

INTRODUCTION

Canadian infestations of Eurasian water-milfoil (*Myriophyllum spicatum* L.) reach nuisance proportions in the Kawartha Lakes in Ontario and in the Okanagan valley in British Columbia (Environment Canada, 1980). The most common control measure is treatment with 2,4-D at a target concentration of 1 mg active ingredient per litre in the water column.

Herbicide application causes a primary sequence of changes in the aquatic flora (Pierce, 1960. Brooker and Edwards, 1975). Primary and secondary effects on non-target organisms, however, are less well documented, experiments often suffering from a lack of replication or being limited to casually observed changes in community structure.

Growth and natality of pisidiid clams have been shown to be excellent indicators of sublethal effects of organic and inorganic

pollutants (Mackie, 1977; 1978; Sandusky and Sparks, 1980). Their filter - and deposit-feeding habits (Benjamin and Burky, 1978) and location at the sediment-water interface make them ideal organisms for evaluating the effects of pollutants which may be adsorbed by sediments.

The present study, part of an holistic investigation of the effects of 2,4-D applied to replicate ponds for *Myriophyllum* control, examines the effects of 2, 4-D butoxyethanol ester (BEE) and dimethylamine (DMA) salt on the survival and growth of pisidiid clams.

MATERIALS AND METHODS

In August 1979, six ponds 20 m x 10 m x 2 m deep were excavated near Winona, Ontario. They were lined with plastic and a layer of sediment, and filled with water from a nearby fish pond. In September 1979 and May 1980, *Myriophyllum spicatum* was planted and by late June it formed a uniform bed in all ponds. Scott et al. (1981) give a complete description of the site, its construction, and the sediment.

The pisidiid, *Sphaerium rhomboideum*, was chosen for this study because of its availability and because the life history of the population used was being studied in detail. In May 1980 young individuals (mean length 5.9 mm) were collected from a permanent pond near Guelph, Ontario, measured (shell length to the nearest 0.05 mm) and placed in growth cages in each pond.

Growth cages consisted of a 15.5. cm length of 11.5 cm O.D. (10.7 cm I.D.) clear acrylic tubing with 3-11.6 cm x 8.2 cm panels removed from the walls and replaced with 0.94 mm opening (8 mesh/cm) nitex mesh. The bottom of the cage was

made of the same nitex mesh glued and sandwiched between the bottom of the tube and a 0.9 cm ht ring of the same diameter tubing. The lids of the cages were made from 2 cm ht rings of 12.3 cm O.D. (11.6 cm I.D.) clear acrylic tubing with the same mesh glued over one end. This cap fitted snugly over the top of the cage. All acrylic to acrylic bonds were made with acrylic solvent cement, while nitex mesh to acrylic bonds were made with a polystyrene type cement. These cages had 63% of the surface area covered with screen and permitted free exchange between the water and sediment of the cage and the pond environment.

On May 29, 1980, 12 cages were prepared for each pond. To each cage was added 150 cm³ of the sediment used in the ponds, 10 willow leaves (Mackie and Qadri, 1978) and 10 pre-measured clams. Cages were worked into the pond sediment until the level of sediment in the cage was the same as that in the pond. Cages were subsequently removed from the ponds without replacement to determine the mean growth rate of clams in each pond. Clams were measured to the nearest 0.05 mm using a Wild stereo dissecting microscope fitted with an ocular micrometer. Because of the range of initial lengths and the lighter colour of the periostracum produced in the experimental ponds, individual clam growth rates could be accurately determined. Growth was measured as mean growth increment, the change in measured lengths over the growth period, and analyses of variance performed for each day that growth clams were sampled. Survival was measured as the number of clams living, expressed as a percentage, when each chamber was sampled. Feeding was assessed by dissecting clams, estimating the relative fullness of the hindgut (between the heart and the posterior adductor muscle), averaging this figure, then expressing the relative fullness as a percentage. The ponds were designated numbers 1 through 6 and treated on June 25, 1980, with an estimated 1 mg 2,4-D per litre in the water column. Ponds 4 and 6 were controls

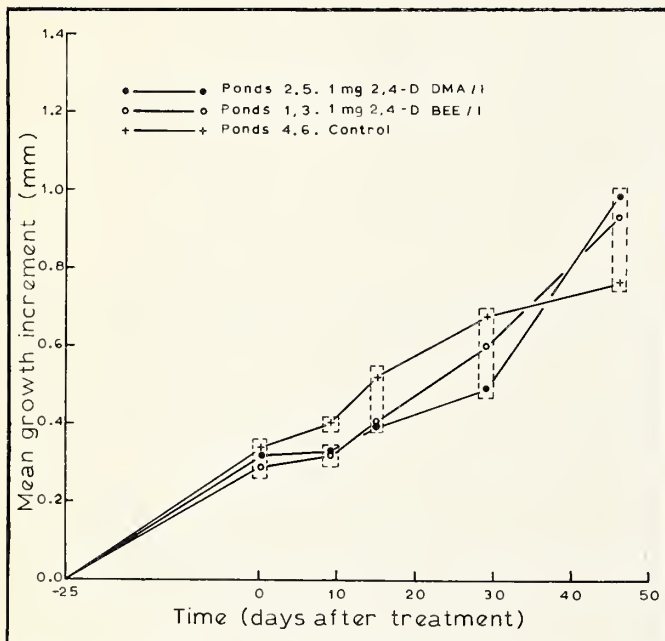


Fig. 1. Mean growth increments (mm) of clams exposed to 1 mg 2,4-D and controls. Points enclosed within the same box are not significantly different at the 95% confidence level.

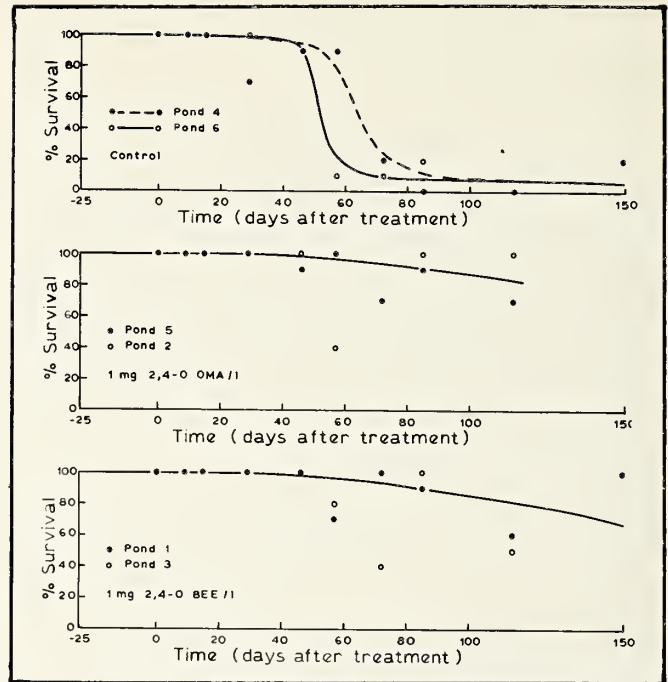


Fig. 2. Survival of clams from growth chambers in ponds treated with 2,4-D and controls (i.e., not treated). Curves fitted by eye.

(i.e., not treated). Ponds 2 and 5 were treated with 2,4-D dimethylamine which was sprayed in 50% active ingredient liquid form on the surface of the ponds. Ponds 1 and 3 were treated with 2,4-D butoxyethanol ester contained in a slow release pelletized form with 20% active ingredient.

RESULTS

Until 46 days after treatment the clams grew moderately well (Fig. 1), the only significant difference in growth increments occurring on the ninth day when both 2,4-D treatments inhibited growth. However, growth quickly resumed, and by day 46 mean growth increments were greater in treated ponds than in control ponds. Growth rates in the control ponds were steady until day 46 when rates started to decline prior to the death of the clams.

Survival (Fig. 2) was good in all ponds until 46 days after treatment. After this time survival in the control ponds fell and by day 72 survival in control ponds averaged 15% while survival in treated ponds averaged 90%.

Clam growth and survival were influenced by feeding. Prior to the death of the clams in the control ponds the relative fullness of clam hindguts (Fig. 3) fell to 0%. In the treated ponds clams fed throughout the summer, although the relative fullness declined after day 28.

DISCUSSION

Both the 2,4-D BEE and the 2,4-D DMA treatments achieved their primary objective of controlling *Myriophyllum spicatum*. Most other plant species present (*Typha*, *Elodea canadensis*, *Potamogeton crispus*, *P. pectinatus*, *P. foliosus*) were also inhibited, the only macrophyte which flourished in the treated ponds being *Chara* sp. (Scott et al., 1981).

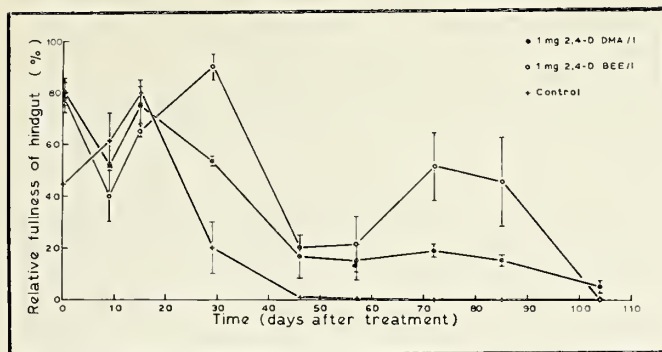


Fig. 3. Relative fullness of clam hindguts. Vertical bars represent one standard deviation.

One mg 2,4-D/1 was not harmful to the clams. Although growth in treated ponds was inhibited between day 0 and day 9, growth resumed shortly thereafter and soon exceeded growth in control ponds. Growth inhibition did not seem to be due to a toxic effect of 2,4-D as concentrations of 2,4-D remained high (Fig. 4) until well after the clams resumed growth. Butler (1965) found that exposure to 3.75 mg, 2,4-D BEE/1 for 96 hours reduced oyster (*Crassostrea virginica*) shell growth by 50%, while 2 mg 2,4-D DMA/1 had no effect. It is possible that the clams simply respond to the introduction of 2,4-D by reducing their activity (and feeding) until they adapt to its presence. The amount of food in clam hindguts supports this hypothesis, the relative fullness showing a decline on the ninth day and recovery on the fifteenth day (Fig. 3). Cope et al. (1970), in a comparable study involving bluegills (*Lepomis macrochirus*), found that anorexia developed almost immediately in fish exposed to 5 and 10 mg 2,4-D propylene glycol butyl ether ester/1. These and lighter treatments subsequently resulted in higher growth rates than in a control pond.

Neither of the 2,4-D treatments caused any mortality among clams (Fig. 2). Although LC₅₀'s have yet to be determined for *S. rhomboides*, 1 mg 2,4-D/1 is considerably below the expected toxic level for either 2,4-D BEE or 2,4-D DMA. The high mortality in the control ponds after 57 days was probably due to shading by the *Myriophyllum*, which continued to grow in the control ponds throughout the summer. When the canopy it produced was dense enough to shade the pond bottom to the point that the periphyton was inhibited, the clams starved to death. This is confirmed by the lack of food in control pond clam guts after day 46, and the poor growth exhibited by surviving clams. In the treated ponds, the *Myriophyllum* collapsed and was decaying by day 14 (Scott et al., 1981), probably resulting in increased light and nutrient availability for the periphyton and enhanced clam survival and growth. The decaying milfoil mat was not dense enough to cause anoxic conditions in the ponds. Other workers (Scorgie, 1980; Boyle, 1979; 1980) have described similar stimulation of the periphyton and benthos following the treatment of aquatic weeds with herbicides.

In summary, survival and growth of pisidiid clams were not seriously affected by treatment with 1 mg 2,4-D BEE/1 or 1 mg 2,4-D DMA/1. Both treatments inhibited clam growth immediately after treatment, but growth resumed between the ninth and the fifteenth day after treatment, and by day 46 exceeded growth in control ponds.

ACKNOWLEDGMENTS

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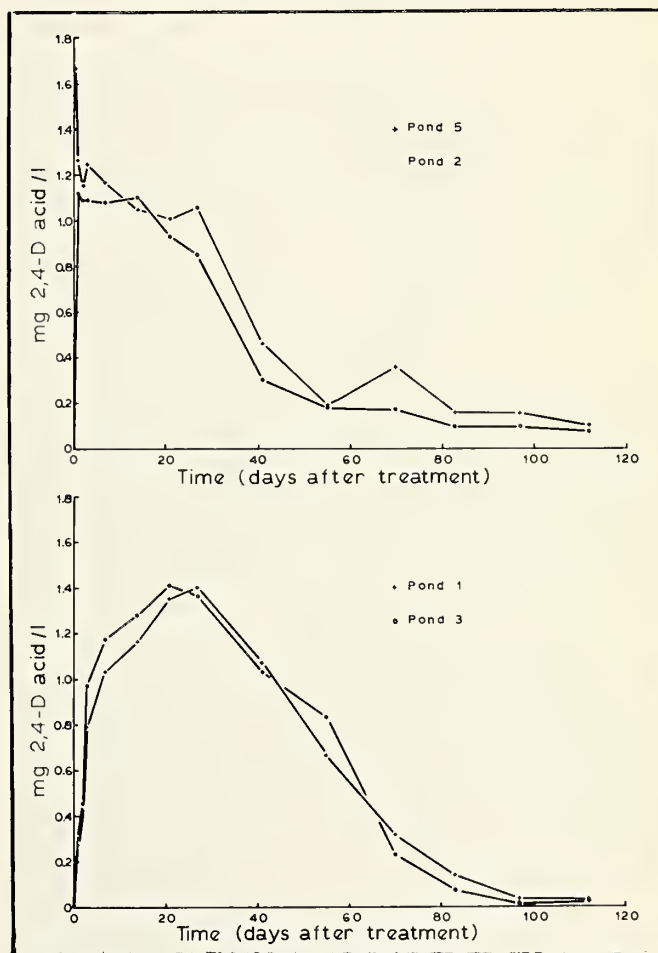


Fig. 4. Concentrations of 2,4-D in amine treated (top) and ester treated (bottom) ponds. Redrawn from Scott et al. (1981).

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THE USE OF GROWTH MODELLING IN STUDIES OF FINGERNAIL CLAMS (BIVALVIA: PISIDIIDAE)

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ABSTRACT

The growth of two populations of fingernail clams were modelled using the Richards function. Fitting of this model allows inferences to be made about maximum size attainable, rate of growth, and growth strategy.

Musculium partumeium length and height growth were modelled and similar shape throughout its ontogeny was verified.

Pisidium casertanum summer and fall growth on a beach in a large lake was also modelled.

Further applications of modelling growth are discussed.

INTRODUCTION

The cosmopolitan freshwater distribution of pisidiid clams has made them a source of interest in both pure and applied ecological research. Although the life histories of several populations have been studied (e.g. Heard, 1965) an analysis of length-frequency data is generally limited to cohort resolution by inspection or using Cassie's (1950) graphical method. A comparison of growth patterns among populations has rarely been quantified. Laboratory studies of treatment effects on growth have involved simple comparison of lengths after fixed time intervals (Sandusky et al. 1979).

Comparisons of growth over a particular time interval (including recruitment to death) are possible if a growth model is fitted to the data. The resultant growth curve parameters can be compared for an overall picture of taxonomic, environmental, or toxicological differences. Green (1973) used such a technique in comparing the growth of two neighbouring intertidal populations of *Macoma balthica*, a marine bivalve.

Growth models can be used to estimate mortality rates (Ebert, 1973). Suitable growth and mortality models can also facilitate estimates of secondary production. Allen (1971) notes that this is the natural extension of the mechanical "Allen curve" technique.

To provide examples of growth modelling with the usually collected size data, the following growth studies were examined.

Data from a weekly sampling of *Musculium partumeium* published by Thomas (1965) were used to compare growth in length to growth in height. This comparison enabled inferences to be made about the ontogeny of shape in the clam. In addition, summer growth of a population of *Pisidium casertanum* collected on a beach of a large lake was modelled.

METHODS

i) Obtaining size data

The lake population of *Pisidium casertanum* was collected from Birdsalls Beach in Rice Lake (Peterborough County, Ontario). Thirty quantitative samples were taken randomly from a specified area of the beach twice monthly in the summer and fall of 1980. Samples were obtained using a hand-held plastic corer (45 cm. ht. x 5 cm. i.d.) fitted with a No. 11 rubber stopper. Each sample was transported to the lab in a 400 ml Mason jar, washed over a 0.64 mm nylon mesh sieve, and hand-sorted. One dram vials containing individual clams in de-ionized water were placed in boiling water to relax the clams before preservation in 70% ethanol. Clams were measured using a Wild stereo-microscope equipped with an ocular scale.

The length-frequency data from each sample were analyzed by inspection or using Cassie's (1950) method to determine the size limits of generations present. Dissection data concerning larval abundance were used to verify the number of generations resolved from the length-frequency histograms.

As previously stated, length and height data for *Musculium partumeium* are from Thomas (1965), who gives details of the collection technique and study site.

ii) The growth model

Growth models are easily conceptualized using a Walford plot (Fig. 1a, c, e) of size at time 't+1' (S_{t+1}) versus size at time 't' (S_t). The bold dashed line in Fig. 1 is the line of no growth (i.e. $S_{t+1}=S_t$). Growth models may have constantly increasing growth increments (exponential), constantly decreasing growth increments (von Bertalanffy), or some set combination of these two (logistic, Gompertz).

Richards (1959) developed a growth model which is a generalization of the von Bertalanffy, logistic, and Gompertz growth curves. The equation, as formulated by Ebert (1980) is:

$$S_t = S_{\max}(1 - be^{-kt})^{-n}$$

where S_t = size at time 't'

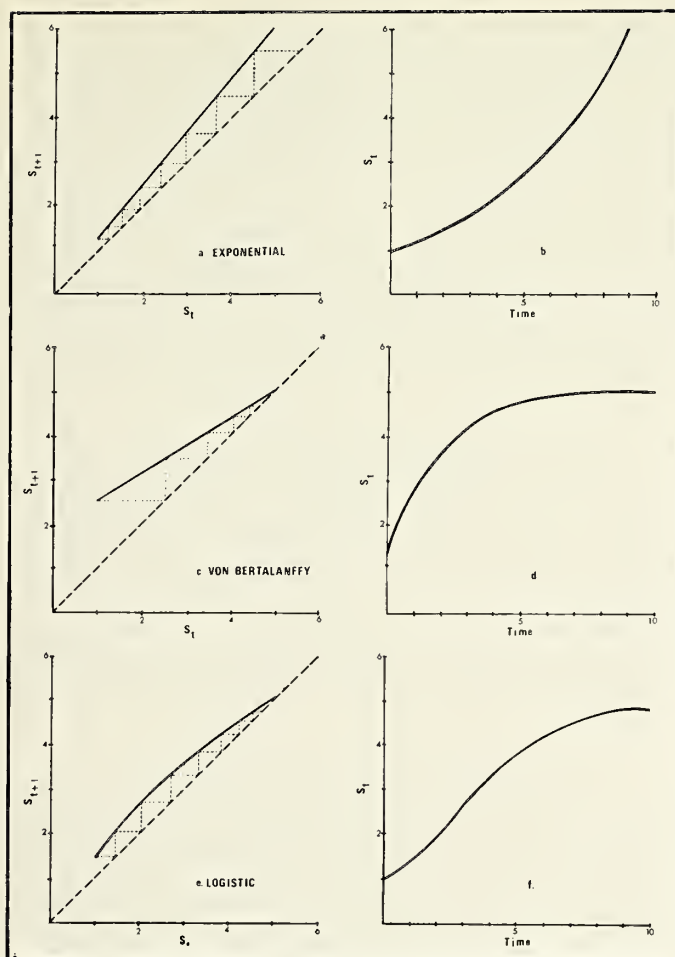


Fig. 1: Walford plots (a, c, e) and their corresponding growth curves (b, d, f) for three common growth models. Walford plots have size at time 't+1' (S_{t+1}) on the ordinate and size at time 't' (S_t) on the abscissa. Steps on the Walford plots illustrate the growth increments during each time interval.

a, b: Exponential growth ($S_t = ae^{kt}$)

c, d: von Bertalanffy growth ($S_t = S_{\max}(1 - be^{-kt})$)

e, f: Logistic growth ($S_t = S_{\max}/(1 + be^{-kt})$)

$S_{\max}$ = maximum size attainable

k = growth rate parameter

n = curve shaping parameter

b = a scaling parameter which just positions the curve on the time axis

When other parameters are held constant, absolute growth rate increases with increasing $S_{\max}$ or k and decreases with increasing n . If n is +1 then the equation is the logistic, whereas $n = -1$ gives the equation for von Bertalanffy growth. As n gets either positively or negatively very large (i.e. $n/1$) the equation approaches the Gompertz growth model.

Ebert's (1980) algorithm was used to estimate the growth curve parameters. His FORTRAN program was rewritten into a set of APL functions available on request. The procedure requires values of S_t and S_{t+1} which are directly obtainable from

resolved length-frequency histograms, mark-recapture data, or laboratory monitoring studies.

iii) Comparison of growth models

Two general situations will occur in comparing growth models. When several replications of each treatment in a study are available, multivariate analysis of variance is appropriate, using the estimated curve parameters as dependent variables.

If only two models are to be compared (as in the present comparison of length and height growth) one may exchange any or all estimated parameters and compute a likelihood ratio as described by Ebert (1980):

$$R(\theta) = \frac{SSE - N/2}{SSE^* - N/2}$$

where SSE = SSE from fitting exchanged params

SSE* = SSE from best-fitting params

N = Number of points fitted

"SSE" refers to the error sum of squares in the fit of the growth curve to the data. $R(\theta)$ will give a measure of the similarity of the two curves either just in shape (exchange n , k) or in both shape and size (exchange n , k , and $S_{\max}$). The best-fitting model has an $R(\theta)$ of 1 (by definition) and others will have progressively smaller $R(\theta)$'s as the goodness of fit decreases. The likelihood ratio is not amenable to tests of significant deviations from unity, but it is useful as a numerical comparison of models.

RESULTS

i) *Musculium partumeium*: length vs. height growth

The growth curves of the length and height of the *M. partumeium* population are shown in Fig. 2. The shapes of the curves are similar, although the size limits of each dimension are different. These conclusions are supported by the likelihood ratios in Table 1, which show ratios close to unity when the shape parameters are exchanged, but values close to zero when shape and size parameters are exchanged.

ii) *Pisidium casertanum*: lake population

Although *P. casertanum* grew very little in the summer of 1980 at this site (Table 2), it is obvious from the growth curve (Fig. 3) that it completed this growth quite quickly (in about six weeks). Thus, although the $S_{\max}$ value (2.00 mm) is much less than that obtained for the *M. partumeium* population (7.34 mm), the k value is larger and the n value is smaller, verifying that this population is reaching its maximum faster than the *M. partumeium* population.

DISCUSSION

i) *M. partumeium*: length vs. height growth

Thomas (1965) shows a relatively constant length/height

Table 1. Likelihood ratios for various exchanges of estimated parameters between models for *Musculium partumeium* length and height growth.

Parameters used	Length model	Height model
Best-fitting (see Fig. 2)	1	1
Exchanged n and k parameters.	0.7682	0.8439
Exchanged n , k , and $S_{\max}$ parameters.	0.0002	0.0128

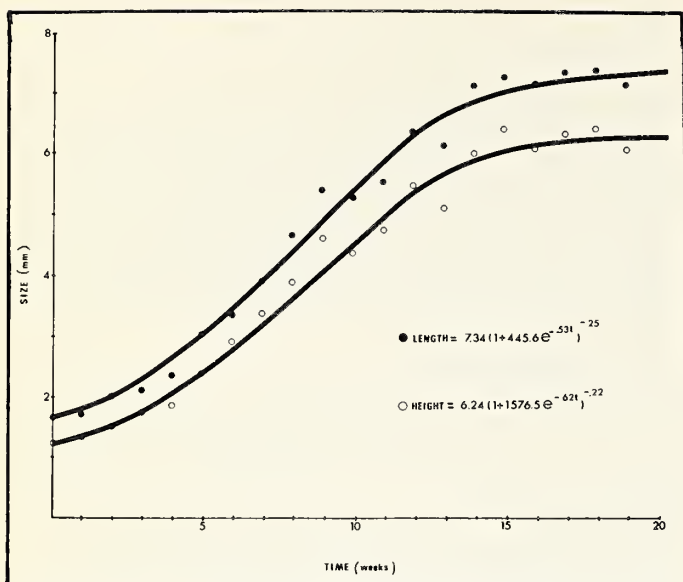


Fig. 2: Growth curves for the length (closed circles) and the height (open circles) of *Musculium partumeium* over a 20 week period.

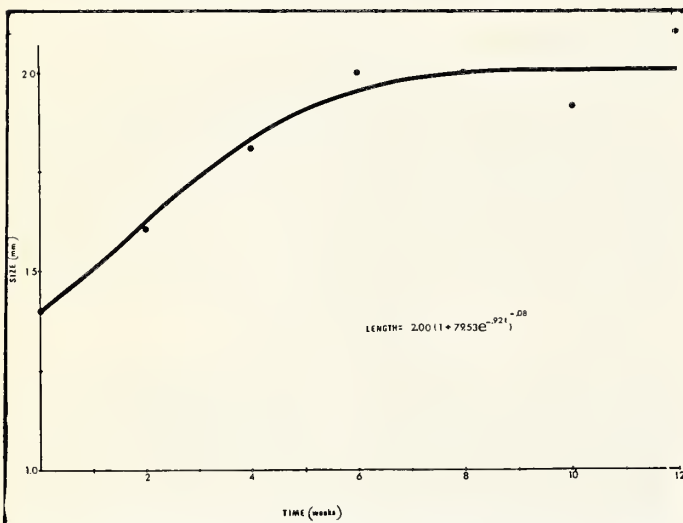


Fig. 3: Growth curve for *Pisidium casertanum* over a 12 week period

ratio throughout the growth of *M. partumeium*. This is supported by the similar growth curves generated for the length and height data. The L/H ratio using the two S_{max} 's is 1.18, which agrees well with Thomas' calculations. One can then infer that the clam has a relatively constant shape throughout its ontogeny.

ii) *P. casertanum*: summer growth

The Rice Lake population seems to follow a pattern common for *P. casertanum* (Heard 1965). They are born in late June or early July and do not achieve full growth or reproduce before winter diapause. In this case they reached only 2.00 mm. Clams the following spring often grow to over 3.00 mm before reproducing and dying. Summer growth to the season's maximum is

Table 2. Estimated length (in mm) of the Rice Lake *P. casertanum* population from July to September, 1980.

Time (weeks)	Mean length (mm, +/- 95% c.i.)
0	1.40 +/- 0.06
2	1.62 +/- 0.04
4	1.82 +/- 0.10
6	1.99 +/- 0.03
8	2.00 +/- 0.03
10	1.92 +/- 0.04
12	2.12 +/- 0.05

rather fast, indicating a faster exploitation of the warmer productive summer waters than the cooler unstable autumn environment.

iii) Problems with growth modelling

The major restriction of the Richards growth function is that the growth curve must eventually reach an asymptote i.e. growth must slow down at some point in the time period under study. Green (pers. comm.) is at present working on a more general model which neither excludes nor requires asymptotic growth.

Modelling can be dangerous if the growth curve is extrapolated beyond known data points. Knight (1968) elaborates on this problem, which is a general hazard in any curve-fitting procedure.

iv) Further applications of growth modelling

The rather simplistic applications of growth modelling carried out here serve only to illustrate the relative ease of fitting models using generally collected size data. Multivariate studies of pisidiid habitat using growth as a dependent variable more or less require a modelling approach. The use of growth modelling in production studies of pisidiids has rarely been attempted. Alimov and Umnov (1978) used such an approach in studying *Sphaerium suecinum* by assuming a von Bertalanffy growth model.

Current investigations of *Pisidium casertanum* by the authors in order to assess the effect of population density on growth will utilize the modelling techniques described.

ACKNOWLEDGEMENTS

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SYMPOSIUM: MORPHOLOGY, ONTOGENY, AND HIGHER CATEGORY SYSTEMATIC OF MOLLUSCS

(This will be published in full in *Malacologia*)

Organizer: *Richard S. Houbbrick*

Anatomical and larval characters and character states, and inferred phylogeny of freshwater mussels (Bivalvia: Unionidae). Bill Heard and Virginia Vail.

The ctenolium of scallop shells: functional morphology and evolution of a key family-level character in the Pectinacea. Tom Waller.

Heads, tails and falling snails. Arthur Caine.

Evolution of the gross anatomy of the digestive tract in the limacisation of the Aulacopods: position of the families Succineidae and Athoracophoridae (Pulmonata: Stylomatophora). Simon Tillier.

On the possible derivation of the Fissurellidae from the Bellerophontacea. James McLean.

Radular functional morphology and adaptive radiation of Rhipidoglossan Archaeogastropods. Carol Hickman.

The origin and evolution of the Busyconinae (Prosobranchia:

Melongenidae): the functional morphology of sand substrate predation. Miroslav G. Harasewych.

A review of the Iravadiidae (Gastropoda: Truncatelloidea) with an assessment of the relationships of the family. Winston Ponder.

Spawn and spawn formation in Prosobranchs as compared with Aplysiomorph Opisthobranchs. Vera Fretter.

Function and taxonomic significance of the pseudopallium in the Eulimidae. Warren Anders.

Potamolithus: morphology, convergence and relationships among Hydrobioid snails. George Davis

Functional morphology of some freshwater bivalve nervous systems: effects on reproductive process and sensory mechanisms in the Sphaeriacea and Unionacea. Louise Kraemer.

The Paragastropoda: a proposal for a new class of Paleozoic Mollusca. Robert Linsley and William Kier.

Speculative functional morphology and morphology which would not function: the examples of *Hyolithes* and *Biconulites*. Ellis Yochelson.

ABSTRACTS OF PAPERS PRESENTED AT THE 1981 MEETING

ABSTRACT

FACTORS AFFECTING THE DISTRIBUTION OF THE HYDROBIID SNAIL *TRYONIA IMITATOR* IN CENTRAL CALIFORNIA

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Tryonia imitator (Pilsbry 1899) lives in high densities in shallow water *Salicornia* marshes. Wide fluctuations of salinity and temperature in this habitat can occur both daily and seasonally. The snails inhabit a wide range of sediment particle sizes. Field observations and laboratory experiments indicate that *T. imitator* is capable of colonizing and surviving in a wider range of habitats than realized in nature. Predation by the shore crab, *Hemigrapsis oregonensis*, appears to limit *T. imitator* to habitats not suitable to themselves. Laboratory and field experiments show that *H. oregonensis* of both sexes and of all sizes greater than 10 mm readily eat *T. imitator* without regard to the snail's sex or size. Hylleberg (1975) has suggested that predation by crustaceans effects the distribution of *Hydrobia* spp. in northern Europe and it is possible that the patchy occurrence in high densities typical of shore dwelling hydrobiids worldwide is due to predation by crustaceans.

NOTES ON THE NEW WORLD MEMBERS OF THE BIVALVE FAMILY DREISSENIDAE

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The family Dreissenidae Gray 1840 contains two Recent genera, *Dreissena* and *Mytilopsis*. *Mytilopsis* Conrad 1858 consists of nine currently accepted species, all of which are byssate, epifaunal forms occurring in coastal bodies of fresh and brackish water. With one exception all are sub-tropical and tropical in geographic range. I consider six of the nine species to be valid: *Mytilopsis leucophaeta* (Conrad 1831), *M. africana* (Van-Beneden 1835), *M. sallei* (Recluz 1849), *M. trautwineana* (Tryon 1866), *M. adamsi* Morrison 1946, and *M. allyneana* Hertlein and Hanna 1949. Four of the six occur in the Americas, *M. leucophaeta* along the Atlantic and Gulf coasts from the Hudson River estuary to Tampico, Mexico; *M. sallei* along the Caribbean coast from the Yucatan to Venezuela and also in the West Indies; *M. adamsi* on the Pacific side of the Panama Canal Zone; and *M. trautwineana* on the Pacific coast of Colombia and Ecuador.

The Dreissenidae are superficially similar to the Mytilidae, but on closer examination are only distantly related. The group most similar to the Dreissenidae may be the Corbiculacea. *Mytilopsis* is considered to be a derived genus and based on conchological characters seems to be more closely related, within the Dreissenidae, to the extinct genus *Congeria* than to *Dreis-*

sena. This may discount other author's claims of a common ancestor in *Congeria* for *Mytilopsis* and *Dreissena*.

Mytilopsis purportedly evolved during the Eocene in the Ponto-Caspian basin. This is inconsistent with the presence of Dreissenidae in the New World, since by the Eocene migrational routes from Europe to the Americas through warm shallow seas were non-existent. It is hypothesized that *Mytilopsis* is much older than previously stated - probably as old as the middle or late Cretaceous.

Little is known of the ecology and natural history of members of *Mytilopsis*. Due to their potential for becoming nuisances as fouling organisms, more research on these unique bivalves is necessary.

ABSTRACT

POPULATION STRUCTURE IN *BIOMPHALARIA GLABRATA*

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Natural populations of the planorbid snail, *Biomphalaria glabrata*, have been studied from Puerto Rico. Electrophoretic analyses showed that 4 of 22 loci examined were polymorphic among these populations. Calculation of F-statistics for inbreeding indicated that these populations were highly structured. Significant differentiation was observed between localities. The snails in Puerto Rico apparently did not represent a single panmictic unit. Despite the potential for self-fertilization, there was little evidence of inbreeding within localities and fit to Hary-Weinberg expectations would suggest random mating among snails within localities but not between localities. These results indicate that migration rates between populations may be small resulting in low levels of gene flow and consequent genetic differentiation of local populations.

ABSTRACT

OXYGEN CONSUMPTION OF *SUCCINEA OVALIS* Say.¹

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During the summer adult snails were placed in Thermos bottles, returned to the laboratory and shell lengths measured to the nearest 0.1 mm. One to three snails were placed in respiration chambers (compensated Scholander type respirometers), equilibrated for one hour at 25°C and oxygen consumption rates recorded. The temperature was then lowered to 15°C, the system equilibrated and oxygen consumption rates remeasured. Subsequently the snails were dried to constant weight at 95°C and corrected for shell to provide ash-free dry weights (AFDW) which are equivalent to tissue dry weights. The above procedure was followed for measurements of both aerial (23

groups) and aquatic (12 groups) respiration. Snails were held underwater during equilibration and measurement of aquatic rates. For the relationship $V_{O_2} = M/W = aW^{b-1}$: $V_{O_2} = \mu l O_2 \text{ mgAFDW}^{-1} \text{ hr}^{-1}$, $M = \mu l O_2 \text{ snail}^{-1} \text{ hr}^{-1}$, $W = \text{mgAFDW}$ of a whole snail, and a & b are regression constants. For aerial respiration a , b and r^2 are 12.63, 0.31, 0.62, and 18.71, 0.32, 0.39 respectively at 15 and 25°C. For aquatic respiration a , b , and r^2 are 41.98, -0.11, 0.88 and 18.82, 0.23, 0.71 respectively at 15 and 25°C. The average Q_{10} for aerial and aquatic rates are 1.75 and 1.73 respectively.

Most adult snails had shell lengths between 14 and 17 mm, however, the AFDWs for snails of similar lengths varied widely. The b values are lower than those of most other snails but may reflect the size range of shells and the variations of tissue weights. Therefore calculated rates for standard size snails of 50 mgAFDW with a shell length of approximately 16 mm are compared. V_{O_2} is 0.85 and 1.31 (aerial at 15 and 25°C) and 0.55 and 0.93 (aquatic at 15 and 25°C). Snails are sometimes found submerged in the field (usually in early spring) and the four to six hours of aquatic conditions during experiments did not appear to have any negative effect on the condition of the snails. These data indicate that during the summer both aerial and aquatic respiration have essentially the same Q_{10} while the absolute level of respiration in water is depressed by 29-35%.

¹Supported by grants from the University of Dayton Research Council, The Ohio Biological Survey and NSF URP Grant no. SPI-7827291.

ABSTRACT

VARIATIONS IN THE SHELLS OF *OBOVARIA JACKSONIANA* Frierson (1912) and *OBOVARIA UNICOLOR* (Lea, 1845).

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Specimens of *O. jacksoniana* and *O. unicolor* were collected from the banks of the Buttahatchie River in Marion County, Alabama and Lowndes and Monroe counties, Mississippi. Shell length, height, width, length of the lateral tooth, distance between the pallial line and the anterior margin of the shell, height of the shell at the posterior end of the lateral tooth and the least distance between adductor muscle scars were measured with a Manostat DIAL 6921 caliper to the nearest tenth of a millimeter. The measurements and the weight of each specimen were used to generate a dissimilarity matrix for each sex separately for both species. The heights and widths of the species were compared relative to shell length with regression analysis and significance was determined by t-tests.

Variations in the shells ranged from typical specimens to specimens with intermediate characteristics. This was especially evident in male specimens. *Obovaria jacksoniana* males ranged from typically ovate specimens with distinctly anterior umbos to specimens with a rounder outline and only slightly anterior umbos. *Obovaria unicolor* males ranged from typically round specimens with dorso-ventrally curved lateral teeth and central umbos to slightly ovate specimens with only slightly curved lateral teeth and central or slightly anterior umbos.

Sexual dimorphism was evident in both species and the females were quadrate but otherwise clearly dissimilar. *Obovaria jacksoniana* females were long relative to height and *O. unicolor*

females were wide and high relative to length. Furthermore, the lateral teeth were always straight in *O. jacksoniana* females and always distinctly curved in *O. unicolor* females. Regression analysis also showed significant differences ($p < 0.05$) in the heights and widths of these species probably as a result of the differences in the female shells. It seems apparent that the females represent two independent species in the Buttahatchie River. Some males may be morphologically similar as a result of genetic variability within the species.

ABSTRACT

ONTOGENETIC CHANGE IN THE MOLLUSCAN RADULA, SOME CASES FROM THE GENUS *CONUS*

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Within the genus *Conus* at least 3 species appear to have a different radular morphology between juvenile and adult. These three species are: *C. pulcher*, *C. fergusonii*, and *C. patricius*. These differences are reviewed, and the reason for radula change is suggested to be change in diet. The time and place of tooth change is suggested based upon the known sequence of production of the *Conus* radula tooth. Limited evidence from other gastropods suggests that this phenomenon may be widespread.

ABSTRACT

LARVAL BIOLOGY OF DEEP-SEA GASTROPODS

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Plankton studies, isotope analysis and biogeographical evidence point out to a vertical migration of veliger larvae in some deep-water gastropods.

ABSTRACT

COMPARATIVE HISTOLOGY AND CYTOCHEMISTRY OF THE MANTLE EDGE OF *BUSYCON CARICA* (GMELIN) AND *BUSYCON CANALICULATUM* (LINNE).

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Busycon carica and *B. canaliculatum* were examined for differences in periostracum formation reflected in histology and cytochemistry of the mantle edge. The periostracum of *B. carica* is smooth and irregularly distributed while *B. canaliculatum* has an extensive organic cover with rows of bristles arranged in regular columns. The bristles are rolled plates of periostracum formed by small ridges of laterally contracted mantle edge.

Homologous structures were found in the mantle edge of both species. The outer shell side epithelium contains a neutral, PAS-, glycoprotein. Subepithelial gland cells in the outer epithelium contain sulfated acid mucopolysaccharide secretory granules. Upon release these may effectively lubricate the

mantle upon retraction. The inner mantle cavity epithelium consists of pigmented, ciliated columnar epithelial cells and goblet cells that contain PAS-, sulfated, acid mucopolysaccharide granules. Mucus covering the inner epithelium is PAS+, sulfated acid mucopolysaccharide. Periostracum is secreted by elongate (40 to 600µm) cells of the supramarginal and distal supramarginal glands. The supramarginal gland contains a PAS+, neutral mucoprotein. The distal supramarginal gland contains a PAS+, weakly sulfated, acid mucoprotein. These periostracum secreting glands empty into a shallow, ciliated supramarginal depression.

The mantle edge of *Busycon canaliculatum* is histologically distinct from the mantle edge of *B. carica*. The inner columnar epithelial cells of *B. carica* tend to be more pigmented than those of *B. canaliculatum*. *B. canaliculatum* possess inner subepithelial gland cells, with PAS+, acidic, non-sulfated, glycoprotein granules. These gland cells are absent in *B. carica*. Their role is unknown. Further investigation of mantle edge cytochemistry may be useful in phylogenetic assessment of Melongenidae.

ABSTRACT

SHELL DEVELOPMENT OF LARVAL AND POSTLARVAL QUEEN CONCH, *STROMBUS GIGAS*

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Queen conch larvae were mass-reared through metamorphosis for the first time under specific laboratory conditions. Scanning electron microscopy was used to document development of the larval and postlarval shell. Photomicrographs made throughout planktonic stages (28 days at 28°C) showed a distinct protoconch I/protoconch II boundary. Randomly distributed ornamentations (1-3 N) of the periostracum became regularly arranged in 4-6 spiral ridges on the protoconch II shell 6 days after hatching. Irregular growth lines were observed in protoconch I, protoconch II and teleoconch shell surfaces; these did not appear to be associated with laboratory events or natural rhythms, although increased handling of larvae prior to metamorphosis was reflected in the shells as a series of pronounced growth lines. *S. gigas* larvae metamorphosed rapidly on suitable algal substrates at mean shell heights of 1.8-1.9 mm (3 1/2 whorls). The protoconch II/teleoconch boundary was distinct with spiral striations (caused by folds in the mantle in contact with the aperture margin) and thickened axial ridges on the teleoconch shell.

ABSTRACT

POPULATION GENETICS OF SOME MARINE MOLLUSKS WITH DIFFERENT MODES OF LARVAL DEVELOPMENT

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The relative degree of genetic variation in 10 populations (7 species) of the marine bivalve superfamily Pholadacea was estimated from data obtained by starch gel electrophoresis. Genetic similarities among the taxa were also assessed. Twenty

enzyme loci were resolved for all 10 populations; approximately 50 individuals per population were electrophoresed. Percent polymorphic loci, average number of alleles per locus, and heterozygosity (H) were calculated for each population. Nie's genetic identity (I) and genetic distance (D) were also calculated. The temperature and salinity tolerance ranges of 2 of the species were determined and compared with indices of the genetic variability for those species.

The species and populations examined were: *Bankia gouldi*, *Teredo navalis*, and *Teredo bartschi* from Barnegat Bay, New Jersey, *Teredo bartschi* and *T. navalis* from Niantic Bay, Connecticut, *Lyrodus floridanus* and *B. fimbriatula* from Miami, Florida, and *T. bartschi*, *L. bipartitus*, and *Martesia striata* from Fort Pierce, Florida. The last species is the only Pholadidae; all the others are in the family Teredinidae.

Levels of genetic variation for the seven species were found to correlate roughly but imperfectly with the amount of time that the larvae spend in the plankton. *Teredo bartschi*, which releases pediveligers, was the least polymorphic. *Martesia striata* and the two species of *Bankia* were the most polymorphic; they have planktotrophic development. However, one population of *T. navalis*, a short-term larviparous species, had very high polymorphism as well. The two populations of *T. bartschi* with the lowest genetic variation were both recently introduced to their present locations. One has undergone drastic population reductions ("bottlenecks" in the jargon of population biology) three times since its introduction.

The breadth of temperature and salinity tolerances of *Teredo bartschi* from Barnegat Bay is not less than that of *T. navalis*, despite the reduced genetic variation of *T. bartschi*. There is also no correlation between latitude and genetic variation in the 10 populations of Pholadacea, nor between genetic variation and the ability to colonize successfully.

The genetic distances confirm the identity of the three populations of *Teredo bartschi*, show that *Lyrodus* and *Teredo* are closely related, and confirm the distance of *Martesia striata* from the other taxa. Although some alleles have been lost in the northern populations of *T. bartschi*, the path of migration of the two introduced populations cannot be determined from the electrophoretic data obtained from the three populations studied so far.

ABSTRACT

PREMETAMORPHIC VELIGERS OF FORT JEFFERSON (DRY TORTUGAS, GULF OF MEXICO) AND BEAUFORT INLET, NORTH CAROLINA

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Some planktonic veligers from the waters surrounding Fort Jefferson and the main channel leading out to sea from Beaufort, North Carolina, are illustrated by *camera lucida* drawings. Diversity and abundance at these two sampling sites are compared with diversity of similar fauna in Kaneohe Bay, Hawaii.

Among those veligers illustrated from Beaufort Inlet are *Cancellaria reticulata* Linne, 1767, *Strombus alatus* Gmelin 1791, *Crepidula plana* Say, 1822, *Epitonium angulatum* (Say, 1830), *Cerithium atratum* (Born, 1778), *Nassarius trivittatus* (Say, 1822), *Littorina irrorata* (Say, 1822), *Cerithiopsis emersoni* (C.B. Adams, 1838) and *C. greeni* (C.B. Adams, 1839).

Among the veligers illustrated from the Fort Jefferson area are

Nassarius albus (Say, 1826), *Cheilea equestris* (Linne, 1758), *Strombus* sp., *Petalochonchus erectus* (Dall, 1888) and *Olivella* sp.

ABSTRACT

BIOLOGICAL OBSERVATION OF SOME *NODILITTORINA* POPULATIONS FROM THE RED SEA

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According to Rosewater (1970) the genus *Nodilittorina* is represented in the Red Sea by two species, i.e. *Nodilittorina* (*Granulilittorina*) *millegrana* and *N.(N.) subnodosa*. Recent research carried out by C.N.R. and G.R.S.T.S. Italian expeditions, focused in the central Red Sea, have led to the finding of scattered populations of a third species, *Nodilittorina* (*Nodilittorina*) *natalensis*, from the Sharm Obhor (Jeddah, Saudi Arabia) and St. John Island (Egypt).

ABSTRACT

THE CLASSIFICATION AND DISTRIBUTION OF THE COWRIES: SOME NEW DIRECTIONS

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Several species complexes of cowries (*Cypraea*; Cypraeidae) are recognized on the basis of features of the protoconch, mantle, radula and female genitalia. Sizes of the apical whorls of the protoconch are correlated with egg size: large, bulbous apical whorls are associated with large eggs (some 600 µm in diameter); small, narrow apical whorls are associated with small eggs (some 90 µm in diameter). The large, sunken protoconchs found in *Cypraea reevei*, *C. friendii*, etc. are those of cowries with direct development. Radular types may be associated with feeding habits. The species complexes of Recent cowries center on the genera and subgenera recognized by F.A. Schilder but fall into two major groups which cross the lines of the three subfamilies established by Schilder. Major species complexes are associated with different geographical regions: about 14 species complexes occur in the Indo-west pacific, one major species complex occurs in South Africa; two species complexes are endemic to Australia; two species complexes are restricted to the western Atlantic and the Caribbean; and one major species complex is shared between west Africa and the west coast of the Americas. It is suggested that the distribution of the major species complexes may be explained as the result of the accidents of geography, for example the separation of Africa and South America in geological time, but that the distribution of some species, such as *C. reevei* of the Indo-west Pacific species complex *Lyncina* in South Australia and *C. citrina* of the Indo-west Pacific species complex *Erosaria* in South Africa, is better explained by classical Darwin-Wallace dispersal theory rather than vicariance.

ABSTRACT

AN UNUSUAL RADULAR FORMULA IN SCAPHOPODA

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The known radular formula of scaphopods is 1-1-1-1-1. While examining the radula of *Laevidentarium callipeplum* (Dall) (USNM 765460) from of Santo Domingo, I found two new tooth-like structures at each side of the rachidian tooth. Out of the five individuals of this species that were examined, this tooth pattern was found in only one specimen. Presently I have examined more than 350 specimens belonging to more than 250 species of scaphopods and this abnormal formula has never been encountered before. No functional significance has been determined.

ABSTRACT

TRICOLIA VARIABILIS — THE MOST VARIABLE GASTROPOD SPECIES KNOWN?

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T. variabilis (Turbinidae or "Phasianellidae") has sexually dimorphic shells and radulae. It has a wide range in the Indo-West-Pacific, and sixteen characters are shown to vary geographically, many of them nonconcordantly. Reasons are given why *T. variabilis* should not be subdivided into many species or subspecies.

ABSTRACT

REPRODUCTIVE PATTERNS OF ENDEMIC SOUTHERN CARIBBEAN PROSOBRANCHS

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Information is given on the egg-masses and characteristics of the development of several Miocene "relict" Caribbean species (*Mazatlanica aciculata*, *Prunum prunum*, *Ficus pilsbryi*, *Polystira* cf. *barretti*).

ABSTRACT

THE DISTRIBUTION, ABUNDANCE, AND ECOLOGY OF THE FAMILY PYRAMIDELLIDAE IN LOWER LAGUNA MADRE, TEXAS

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Fourteen species of the family Pyramidellidae were collected in Lower Laguna Madre, including *Pyramidella crenulata*, 3 species of *Odostomia*, 4 of *Eulimastoma*, 2 of *Sayella*, and 4 of *Turbonilla*. Aspects of their distribution and ecology in relation to sediment type, oyster reefs, grassflats and potential hosts will be presented.

ABSTRACT

RELICT PLIOCENE MOLLUSCAN FAUNAS
IN THE CARIBBEAN
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The recent Caribbean molluscan province is shown to consist of a faunal mosaic in both time and space. Two areas, one off Yucatan, Mexico and one off northern Honduras, contain relict elements of the Neogene Caloosahatchian Province. The other area, off northern Colombia and Venezuela, contains an intact Pliocene fauna from the Neogene Gatunian Province. An ecological hypothesis for the persistence of these relict pockets into the recent is conjectured.

ABSTRACT

WHAT IS DIASTOMA? SYSTEMATIC POSITION OF THE
DIASTOMATIDAE
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Diastoma melanioides is the living survivor of a long lineage of snails which occurred in the Tethys Sea during the Tertiary. This species lives in southwestern Australia and its anatomy places it in the superfamily Cerithiacea. Anatomy, shell characters and the fossil record indicate familial status for *Diastoma*. Smaller Cerithiacean genera such as *Finella*, *Alaba*, and *Bittium* are excluded from this taxon.

ABSTRACT

PROTOCONCHS PAST AND PRESENT: A COMPARISON OF
SOME FOSSIL TURRIDAE WITH THEIR WESTERN
ATLANTIC AND EASTERN PACIFIC DESCENDENTS
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Environmental differences between the warm water Western Atlantic and Eastern Pacific provinces could have caused adaptive reproductive responses in the two faunas since the closing of the central American land bridge more than 2 or 3 million years ago. However, changes toward prolonged planktotrophy or lecithotrophy, as determined by protoconch characters, are not apparent when recent species in the Turridae genera *Polystira*, *Cerodrillia*, *Hindsiclava*, *Mitrolumna* and *Glyphostoma* are compared with fossil Miocene and Pliocene species from the old Caribbean.

Both recent faunas contain numbers of species with planktotrophic and lecithotrophic larvae. Two of the genera, *Polystira* and *Glyphostoma* have only species with planktotrophic larvae in the Eastern Pacific. This may be a reflection of the reproductive condition of their Miocene ancestors, not adaptation to present conditions.

ABSTRACT

SHELL DAMAGE AND REPAIR: A RARE SILURIAN EXAMPLE
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Cases of shell repair after attempted predation are common among Recent gastropods, but rare in the lower Paleozoic. A specimen of *Euomphalopterus*, an astraeiform archaeogastropod, which survived several major episodes of shell damage is described from the Silurian of Sweden.

ABSTRACT

LAND SNAILS AND ENVIRONMENTAL CHANGE AT
BARBERS POINT, OAHU, HAWAII
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Study of subfossil land snails from archaeological and paleontological sites at Barbers Point in the karstic Ewa Plains of Oahu, Hawaii, shows that prior to human occupation this relatively arid region was inhabited by a fauna of ca. 15 native terrestrial mollusk species. Taxa present were Helicinidae (1 sp.), Achatinellidae (=Tornatellinidae; ca. 4 spp.), Pupillidae s. l. (4 spp.), Amastridae (3 spp.), Endodontidae (2 spp.), and Succineidae (ca. 1 sp.). This fauna is indicative of a region of open-canopy dry-forest and grassland, a conclusion consistent with the paleoenvironment inferred by other workers on the basis of botanical evidence. The apparent advent of human influence is marked by the appearance of *Lamellaxis gracilis* (Subulinidae), a species known to have been introduced to Oceania prehistorically but not yet recorded from dated prehistoric context in Hawaii. A marked increase in the relative abundance of exotic taxa, including species known to have been introduced during the historic period, occurs coincidentally with the extinction of most native land snail taxa. The historically-introduced *Gastropoda servilis* (Pupillidae) is now the most abundant land mollusk in the area, although native species of *Lamellidea* and *Tornatellides* (Achatinellidae), *Lyropupa* (Pupillidae), and *Succinea* (Succineidae) are also present. The observed replacement of native land snail species by exotic taxa is undoubtedly the result of man-caused environmental modification, although the absolute chronology of these ecological changes has not yet been determined. It is hoped that further work will demonstrate the relative importance of the prehistoric and modern human inhabitants of Oahu in this process of faunal succession.

ABSTRACT

NAIADS FROM THE MOBILE RIVER SYSTEM,
PAST AND PRESENT
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Freshwater mussel remains recovered from three protohistoric indian sites in Alabama and Mississippi were analyzed and compared with recent collections. The results indicate that in

recent times both overall abundance and species diversity have decreased. Naiads were not found in streams near the two sites in Alabama on collecting trips made in 1978 - 1980. The most extensive analysis concerned the Mississippi site, on the upper Tombigbee River. The number of species collected from this river has declined from more than twenty-five in 1935 to only sixteen during field work in 1978 and 1980. In addition to changes in the overall naiad fauna, the relative contributions of many species have also changed, with eight showing an increase and nine a decrease. One species, *Plectomerus dombeyanus* (Valenciennes), appears to have become established in the upper Tombigbee River within the last three hundred years. Changes in the naiad population structure are related to changes in water quality due to increased pollution, siltation, and, most importantly, man made alterations of river channels, i.e. channelization and dam construction.

ABSTRACT

MAXIMAL LAND SNAIL DIVERSITY - NEW ZEALAND

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The central North Island of New Zealand is shown to have a climax community of 70-75 microsympatric land snail species, whereas most areas of the world have only 5-10 species occurring microsympatrically.

ABSTRACT

A MORPHOMETRIC ANALYSIS OF SHELL CONVERGENCES
AMONG *MESODON*, *TRIODOPSIS*, AND *ALLOGONA*
(PULMONATA: POLYGYRIDAE).

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Pilsbry's (1940) monograph of Polygyridae called attention to four digeneric pairs of subgenera exhibiting convergence in shell shape. An objective assessment, using the logspiral growth model and multivariate analyses, revealed how remarkably close the convergences actually are. It remains to be determined whether these convergences represent adaptations to similar environments or random parallelisms resulting from shared alleles.

ABSTRACT

TAXONOMY AND EVOLUTION OF THE GENUS
MONADENIA (GASTROPODA: PULMONATA)

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Three subgenera of *Monadenia* Pilsbry, 1895, are recognized: *Monadenia sensu stricto*, inhabiting a humid coastal strip from southeast Alaska to central California; *Corynadenia* Berry, 1940, patchily distributed along the west slope of the central Sierra Nevada; and a new subgenus mostly confined to the Klamath Mountains of California, where it is parapatric with

Monadenia s.s.

Cladistic analysis groups *Corynadenia* with the new subgenus, with *Monadenia s.s.* less similar to either. The distribution of apomorphies falsifies all possible phylogenetic trees for the group except that which is isomorphous with the cladogram. Consequently, the proposed phylogenetic history of *Monadenia* consists of (1) a dichotomy between *Monadenia s.s.* and the common ancestor of *Corynadenia* and the new subgenus, followed in time by (2) a dichotomy between the latter two subgenera.

Three fossil forms referred to *Monadenia* are present in the John Day Formation (late Oligocene to early Miocene) of central Oregon. Shell types resembling modern *Monadenia s.s.* and the *Corynadenia*-new subgenus group are present. The Bridge Creek Flora (age 31.5 million years) from the lower member of the John Day Formation represents a mixed mesophytic forest dominated by broad-leaved deciduous trees, in a temperate climate with ample summer rainfall—similar to modern hardwood forests of eastern North America and eastern Asia. The source of the John Day land mollusks is the vertebrate-rich middle member, about 25 million years old; contemporaneous floras are also mixed mesophytic, possibly somewhat warmer than the Bridge Creek Flora. The Cascade Range was not a significant climatic or vegetational barrier at this time. The inferred environment may have supported greater intrageneric snail diversity than now seen in any forests of the west, much as the hardwood forests of the eastern United States now support diverse Polygyridae. Part of the early diversification of *Monadenia* probably involved habitat partitioning between ground-dwelling and arboreal species.

With subsequent shift from summer-wet to summer-dry climate, and depauperization of the woody flora by the Pliocene, substantial allopatry between the two stocks of *Monadenia* may have arisen, with the *Corynadenia*-new subgenus group inhabiting the drier interior regions and *Monadenia s.s.* exploiting a tendency toward eurytopy in humid environments. Thermal parameters now limit the ranges of the subgenera. A modern isothermal configuration suggests a model for conditions that may have enforced geographic separation between *Corynadenia* and the Klamath Mountains subgenus, leading to their differentiation.

ABSTRACT

GAMETOGENESIS IN THE LAND SNAIL, *TRIODOPSIS*
MULTILINEATA

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The ovotestis consists of numerous clusters of slender lobes. The lobes are surrounded by blood spaces. Numerous blood vessels course between the lobes on their way to digestive gland tissue peripheral to the ovotestis in the whorl. Each lobe is bounded by a delicate squamous epithelium. This limiting epithelium encloses gametogenic cells and accessory cells.

Those gametogenic cells which will become oocytes remain in contact with the limiting membrane and differentiate within a compartment formed by accessory cells. When the oocyte reaches its definitive size it ruptures from the compartment and is free to move toward the tributary duct of the little hermaphroditic duct. The nucleus of the oocyte remains in prophase of the first meiotic division throughout its period of differentiation;

meiosis resumes only after fertilization. The single, conspicuous nucleolus undergoes a cycle of vacuolization and extrusion of substance into the nucleoplasm.

The majority of the gametogenic cells differentiate as sperm cells. Spermatogonial cells become loosely aggregated in spherical clusters. As meiosis proceeds, cells of the cluster elongate; the nuclei are peripherally located. The heads of differentiating spermatids associate with a large accessory cell and are located adjacent to the limiting membrane of the lobe. As the tails elongate, irregular blebs of cytoplasm are evident along the tails and terminally. In the final stages of differentiation the compact heads remain closely associated with the accessory cell until the time of release and movement to the little hermaphroditic duct for storage.

ABSTRACT

FRESHWATER CLAMS OF LAKE LEWISVILLE, TEXAS

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A survey has been completed of freshwater clams in Lake Lewisville, an impoundment on the Trinity River in northcentral Texas. A total of 17 species were recovered; all are native species except *Corbicula*. Natural and anthropogenic factors in distribution of clam species were discussed. Human impact upon the unionid resources of Lake Lewisville were reviewed.

ABSTRACT

NAIADES (MUSSELS) OF THE LOWER OSAGE RIVER,
TAVERN CREEK, AND MARIES RIVER, MISSOURI

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A survey of the naiades (mussels) at 43 sites in the lower Osage River Basin in central Missouri between May and September 1980 revealed a total of 36 species; 34 in the lower Osage river, 24 in Tavern Creek, and 26 in the Maries River. Three species, *Anodonta grandis corpulenta*, *Arcidens confragosus*, and *Obovaria olivaria*, all found in the lower Osage River, had not previously been reported from the lower Osage River Basin. *A.g. corpulenta* had not previously been reported from the Osage River Basin. *Fusconaia ebena*, previously collected in the lower Osage River Basin, was not found.

A total of 21,593 living naiades were examined: 18,038 at 23 sites in the lower Osage River, 1,284 at 9 sites in Tavern Creek, and 2,271 at 11 sites in the Maries River. Ten species of naiades comprised 92.0% of the living naiades found in the lower Osage River Basin: *Megalania nervosa* (51.5%), *Amblema plicata* (9.1%), *Quadrula pustulosa* (8.1%), *Cyclonaias tuberculata* (4.9%), *Lampsilis radiata luteola* (4.8%), *Lampsilis ventricosa* (3.2%), *Pleurobema coccineum* (2.8%), *Fusconaia flava* (2.7%), *Elliptio dilatata* (2.6%), and *Potamilus alatus* (2.3%). *M. nervosa*, *Q. pustulosa*, *C. tuberculata*, and *A. p. plicata* were the dominant species in the lower Osage River; *L. r. luteola*, *P. alatus*, *A. p. plicata*, and *L. ventricosa* were the dominant species in Tavern Creek; and *A. p. plicata*, *L. r. luteola*, and *L. ventricosa* were the dominant species in the Maries River.

Lampsilis orbiculata, listed as endangered on the United States List of Endangered and Threatened Wildlife and Plants, was collected alive at nine sites in the lower Osage River. Live *Cumberlandia monodonta*, under Notice of Review for possible addition to the above list, were collected at seven sites in the lower Osage River. *L. orbiculata* and *C. monodonta* comprised 0.1% and 0.3%, respectively, of the living naiades found in the lower Osage River. These two species were not found in Tavern Creek or the Maries River. Four species, *A. g. corpulenta*, *A. confragosus*, *Elliptio crassidens crassidens*, and *O. olivaria*, classified as rare or endangered in Missouri, were also found in the lower Osage River.

The lower Osage River, Tavern Creek, and Maries River provide generally favorable habitat for naiades throughout most of their lengths except for reaches of the Osage River adjacent to three large, commercial gravel dredging operations. No living naiades were found in areas dredged by the three commercial gravel dredging operations. Removal and processing of sand and gravel at these dredging operations significantly increases the turbidity of the river up to 3,700 feet downstream during dredging and washing and increases the depth of the Osage River at the dredging site for an indefinite period of time. Continued dredging in areas previously dredged at all three commercial dredging operations is unlikely to have a serious adverse impact on *L. orbiculata* and *C. monodonta* if the river configuration is not altered and dredging is not expanded downstream at two of the sites. Releases of water from the hypolimnion of Lake of the Ozarks appear to inhibit normal development of naiad populations in the 16 miles of the Osage River immediately below Bagnell Dam.

ABSTRACT

A RECONSTRUCTION OF THE FRESHWATER MOLLUSCAN
FAUNA OF THE LITTLE TENNESSEE RIVER,
EAST TENNESSEE

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The freshwater unionid molluscan fauna of the Cumberland and Tennessee River systems was the richest in the world. Historically, this fauna was not extensively surveyed; subsequently the molluscan faunas of some rivers have only been incidentally reported. The reported unionid fauna from the Little Tennessee River in East Tennessee is depauperate (23 bivalve and 9 pleurocerid gastropod species) compared with similar streams in the headwaters of the Tennessee River. Areas which historically are faunistically depauperate can be examined using materials from the archaeological record, an important zoological resource. It is possible to reconstruct the local freshwater molluscan fauna through the careful identification and analysis of archaeological molluscan remains. The University of Tennessee, Knoxville, has conducted such investigations in the Little Tennessee River Valley and recovered freshwater molluscan remains from tightly dated contexts. These remains from four sites located along the Little Tennessee River in East Tennessee provide the requisite data base for and examination of the river's former molluscan fauna. The composite archaeological molluscan fauna identified from the little Tennessee River Valley (42 bivalve and 8 gastropod species) clearly docu-

ments the river's formerly rich and diverse fauna. This reconstructed molluscan fauna would have been comparable to the unionid fauna Ortmann reported for the Tennessee River at Knoxville or from the Clinch River in East Tennessee. The archaeological sample also contained obese examples of the spiny river snail (*Io fluviatilis*) which C.C. Adams did not report from the Little Tennessee River in his monograph of the genus. This fauna was extant in the Little Tennessee River until the early 19th century but was not reported in the 1850's and is essentially extirpated from the river today.

ABSTRACT

MUSSELS FROM THE GALAPAGOS RIFT

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In 1977, a geological expedition to hydrothermal vents at the Galapagos Rift (an area of sea-floor spreading east of the Galapagos Ilds. at 2500 m depth) discovered, photographed and collected specimens of a hitherto unknown fauna. This discovery was further investigated by a biological expedition to the site in 1979. Mussels collected by both expeditions were examined as to anatomy and shell morphology. They belong to the family Mytilidae but not to the deep-sea genera *Crenella*, *Dacrydium*, *Amygdalum* or *Idasola*. The shells superficially resemble the genus *Modiolus* Lamarck but differ as to pallial line and posterior retractor muscle scars from most species of the genus. The galapagos shells most closely resemble *Modiola abyssicola* Knudsen 1970, but comparison of the anatomy of the two species revealed major differences in mantle fusion, siphons, and digestive tract. On this basis, the author concludes that the galapagos mussels are definitely a new species and probably a new genus.

ABSTRACT

NEWLY DISCOVERED ANATOMICAL CHARACTERS

USEFUL IN CLASSIFYING OYSTERS

(OSTREACEA: GRYPHAEDAE AND OSTREIDAE)

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The flesh of 23 species, representing 12 genera, was studied. In the Pycnodontinae (only living subfamily of Gryphaeidae) the lateral extensions of the outer labial palp are fused together medially, covering the inner palp. This also occurs in the Lophinae and to a lesser extent in some genera of Ostreinae (the two recognized subfamilies of Ostreidae). In Pycnodontinae and Lophinae the mantle is thin, and its inner surface is papillate to varying extent. In some Ostreinae the surface is not papillate, and the mantle is seasonally thickened for glycogen storage. The Lophinae and some Ostreinae have a prominent, finger-like process extending from the outer lip of the anus. The process is absent in other Ostreinae, and modified in the Pycnodontinae. All living oysters have a neobranch, of tubular vascular channels protruding through the medial surface of the mantle lobes, forming a series of ridges near, and normal to the mantle margin. The precise pattern of the ridges varies among genera.

Unlike the Ostreidae, the Gryphaeidae have the auricles of the heart extensively outpocketed and broadly fused to the ventral surface of the pericardium. In Gryphaeidae the major parts of the kidney are scarcely outpocketed; the kidney has an extensive medial sac covering the dorsal surface of the adductor muscle and extending down its posterior surface as a long caecum, to the right of the rectum. In Ostreidae the kidney has no posterior caecum, the medial sac is reduced to a small transverse tube across the antero-dorsal curvature of the adductor muscle; the major parts of the kidney are thin tubes, extensively outpocketed as short, branched caeca.

The left promyal passage of the excurrent mantle chamber is open only in the gryphaeid, *Hyotissa hyotis* (Linne, 1758). The right promyal passage is open in all genera except those of the Lophinae and some Ostreinae.

ABSTRACT

VARIATIONS FOUND IN *MULINIA LATERALIS*
IN THE NORTHERN GULF OF MEXICO

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Mulinia lateralis is commonly collected throughout the northern Gulf of Mexico. During recent examinations of large numbers of these bivalves, considerable variation was noticed in the shape and size of the pallial sinus. This variation consisted of the relative length and width, as well as subjective differences in the overall shape of the sinus. *Mulinia lateralis* is a common estuarine bivalve previously reported from Canada to Cuba and through the Gulf of Mexico. The aforementioned morphological variations have led to a more detailed examination of the species and the designation of two forms. An attempt was made to correlate a specific morphological form with ecological parameters. After an analysis of temperature, salinity, and sediment size, a trend was noticed linking the presence of Form A (short, rounded sinus) with sediment having a high silt fraction. Form B (long, tapering sinus) was predominant in sediments with higher sand fractions. Variations in the size of the pallial sinus were not found to be statistically significant. Preliminary conclusions suggest that the description of a new species is unwarranted.

ABSTRACT

ISOCITRATE DEHYDROGENASES OF *CRASSOSTREA*
VIRGINICA GMELIN

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Sessile bivalve molluscs are known as facultative anaerobes. There is a large volume of literature concerning anaerobic pathways in these animals, but only sparse evidence of oxygen utilizing biochemical systems. Thus demonstration of an aerobic series of reactions such as the Krebs Cycle would lead to a better understanding of sessile bivalve metabolism.

NAD⁺-dependent isocitrate dehydrogenase is a control enzyme of the Krebs Cycle. This enzyme has not previously been reported in sessile bivalves. However an NADP⁺-dependent isocitrate dehydrogenase from *Mytilus* has been

studied.

NADP⁺ and NAD⁺ dependent isocitrate dehydrogenase activities have been found in extracts of all tissues of the American oyster, *Crassostrea virginica* Gmelin. The specific activity of the NAD⁺ reducing enzyme is highest in adductor muscle extracts and lowest in those of the digestive diverticula. The specific activity of the NADP⁺ dependent isocitrate dehydrogenase was equally high in mantle and digestive diverticula homogenates and lowest in adductor homogenates.

The NAD⁺-dependent isocitrate dehydrogenase has been separated from the NADP⁺ dependent activity. Characteristics of the former are: a pH optimum between 7 and 7.5; inactivation by iodoacetamide; $K_m(\text{Mn}^{2+})$ equal to 1.12 mM; $K_m(\text{Mg}^{2+})$ of

0.61 mM. The $K_m(\text{isocitrate})$ is 1.58 mM in the absence of ADP

and 0.66 mM in the presence of 1mM ADP. Nucleotides also affect reaction velocity: ATP, CTP, GTP and UTP inhibit reaction rate; ADP and GMP increase reaction rate.

Thus NAD⁺-dependent isocitrate dehydrogenase may be a regulatory enzyme in the oyster.

The authors wish to thank Dr. Thomas E. Smith for his support and advice and Dr. Allen R. Rhoads for the gift of the guanine nucleotides.

ABSTRACT

SHELL ULTRASTRUCTURE OF *CORCULUM* SPP. (RÖDING) (BIVALVIA: CARDIACEA)

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Fractured shell fragments of *Corculum cardissa* (L., 1758) and *C. dioneum* Broderip were examined by scanning electron microscopy. Structural differences were noted between the anterior and posterior shell in *C. cardissa* and also in *C. dioneum*. Differences included a thick periostracum, crossed lamellar outer shell layer, thin pallial myostracum, complex crossed-lamellar inner layer and probably an innermost layer or nacre in anterior shells. Posterior shell demonstrated window structures composed of fibrous crystals whose axes run perpendicular to the shell surface. Shell structure of *Corculum* spp. was compared with that of *Fragum fragum* (L., 1758) and *Hemicardia hemicardia* and demonstrated radical differences, especially in the posterior shell structure. The biology of *Corculum* spp. and the relationship between these bivalves and endosymbiotic zooxanthellae with respect to shell ultrastructure were discussed.

ABSTRACT

COMPARATIVE CONCHOLOGY AND ANATOMY OF TWO SYMPATRIC SPECIES OF *TRANSENNELLA* (BIVALVIA: VENERIDAE)

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The genus *Transennella* Dall 1883 is represented on the west coast of the United States by two morphological entities whose systematic status has been in question. Examinations of

shell form and soft part anatomy, as well as ecological observations, support the recognition of the two entities as distinct species. The two species may be distinguished by shell outline, pigmentation, sculpture, hinge characteristics, siphon structure and the anatomy of the digestive system. Study of taxonomic literature and museum collections was used to determine the name *T. tantilla* (Gould, 1852) for one of the species, and a new species as yet undescribed, and the sympatric geographic ranges of each.

ABSTRACT

PRIMARY LIGAMENT AND LITHODESMA STRUCTURE AND FUNCTION IN *MYTILIMERIA NUTTALLI*

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Many members of the bivalve subclass Anomalodesmata possess a small calcareous ossicle partially surrounded by the organic hinge ligament. This ossicle, the lithodesma, may function in the abduction of the valves. This function is reinforced by the microstructure of the lithodesma in the ascidian endosymbiont bivalve *Mytilimeria nuttalli*. The ligament surrounds all but the ventral and posterior-most parts of the lithodesma and is reinforced with aragonitic fibers that run perpendicular to the ossicle's surface. The ossicle is composed primarily of a compact micropismatic structure. This may offer resistance to stresses should host tunicate growth obstruct free abduction. Tall prisms reminiscent of typical molluscan myostracal structure, compose the ventral lithodesmal surface. This surface ensures close contact between secretory mantle epithelium and the lithodesma and allows growth. The dorsal lithodesmal surface is rugose, forming a series of well defined growth bands and lines. Major growth bands along the lithodesmal dorsum show an arborescent type of growth. These are likely deposited during periods of rapid growth. Minor growth bands are composed of smaller, tightly packed prisms. These represent lines of discontinuity. The rugosity of this surface assures a firm connection between lithodesma and ligamental resilium. Interesting differences among lithodesmas of various families of the Anomalodesmata include shape and position. Ultrastructural variations among these groups have yet to be explored.

ABSTRACT

COMPARATIVE MORPHOLOGY OF GLADIUS CROSS-SECTIONS IN THE FAMILY OMMASTREPHIDAE (CEPHALOPODA: TEUTHOIDEA)

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Cross-sections of gladii from 17 species in 10 genera from the family Ommastrephidae were examined. Sections were prepared at four corresponding levels to permit direct comparison among species.

Observed morphology demonstrates a suite of previously undescribed characters exhibiting components of variation relating to intermediate and lower taxonomic levels. These observations indicate a need for a re-evaluation of the present subfamilial groupings within the family Ommastrephidae and

systematic revision of some genera.

This discovery has application to the investigation of fossil gladii and the establishment of evolutionary lineages. In addition these characters may be utilized in the identification of gladius remains encountered in the stomach contents of predator species.

ABSTRACT

SEASONAL SEXUAL MATURATION IN THE OCTOPUS *ELEDONE CIRRHOSA*.

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Relative ovary size and mean egg length have been estimated for females of the common octopus of the North Sea, *Eledone cirrhosa* (Lam.). The seasonal incidence of maturation stages will be described for a 3 year period and related to the life cycle of the species.

ABSTRACT

THE STRANDING OF A GIANT SQUID, *ARCHITEUTHIS*, ON PLUM ISLAND, MASSACHUSETTS

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ABSTRACT

A fine specimen of giant squid, *Architeuthis*, was discovered stranded on the beach of the Parker River National Wildlife Refuge, Plum Island, northeast of Newburyport, Massachusetts on 2 February, 1980. The specimen frozen when found at high tide mark in early morning, was transported to the New England Aquarium in Boston. Dr. Kenneth J. Boss, Museum of Comparative Zoology, Harvard University, and I were informed of the discovery immediately, and were provided the opportunity to examine the specimen at the Aquarium, where it was weighed, preserved in buffered formalin, and measured. The specimen was placed on exhibit in the Aquarium for several months. Weighing approximately 205 kg (450 pounds), the specimen was in relatively sound condition, with the exception that both tentacles and the tips of all arms were missing. At the time of preservation, the dorsal mantle length measured 2.0 m (6.5 ft), and the longest arm, the right IV, 1.3 m (4.3 ft). Based on interpolation from entire specimens, the Plum Island squid was an estimated 8.5-9.1 m (28-30 ft) in total length. This stranding represents only the second recorded in Massachusetts; the first was from Cape Cod in 1909. Fewer than ten specimens of *Architeuthis* have been documented from the waters of continental United States.

In June 1980, the Plum Island specimen was transferred to the National Museum of Natural History, Smithsonian Institution, where it was placed on temporary exhibit in 1981, prior to detailed anatomical studies being conducted by Boss and Roper.

ABSTRACT

LARVAL DISTRIBUTION OF A EURYHALINE SQUID NEAR ITS NORTHERN RANGE LIMIT

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Planktonic *Lolliguncula brevis* (dorsal mantle length 15 mm) can be distinguished from similar-sized *Loligo* spp. by differences in chromatophore patterns. The most consistent character throughout development is a cluster of three chromatophores posterior to the eyeball on the ventral surface of the head on *L. brevis*. The corresponding cluster on *Loligo* consists of four chromatophores. Also *L. brevis* has more total ventral chromatophores and fewer total dorsal chromatophores than similar-sized *Loligo*, intensifying the "reverse countershading" pattern characteristic of neritic squid larvae.

During several years of year-round zooplankton sampling of the continental shelf and estuaries, planktonic specimens of *L. brevis* were collected north of Cape Hatteras only during August-October. All specimens taken inside Chesapeake Bay were in subsurface samples from the eastern side of the bay whereas all specimens from the nearby continental shelf came from surface samples. Based on the known circulation in the area, spawning probably occurs in the vicinity of the bay mouth. This distribution and the late spawning season indicate that *L. brevis* is not as tolerant of low salinities near its northern range limit as it is in warmer latitudes.

LEUCOPOIESIS IN THE NEWFOUNDLAND BAIT SQUID, *ILLEX ILLECEBROSUS*

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It is believed that cephalopod blood cells are formed in the white body (a ring of soft tissue which surrounds each optic ganglion). Light and electron microscopy reveal structural details highly indicative of a leucopoietic function. The white body is surrounded by a fibrous capsule from which extensions serve as septa; traversing adjacent tissue and dividing the cells thereof into irregular groupings. Throughout the tissue, one can observe cell types characteristic of a developmental series from stem cell to mature leucocyte. Data from Latex injections and angiography indicate the tissue is well vascularized. However, experimental proof is needed to verify the organ's function.

ABSTRACT

COMPARATIVE MORPHOLOGY OF STATOLITHS OF TWO SQUID SPECIES

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Despite intraspecific and intra-individual structural variations in statoliths, the size of the teuthoid statolith is directly correlated with the size of the fresh or frozen adult squid over the size range of 160 to 255 mm mantle length.

Different areas of the statoliths are characterized by different crystal arrangements. It is speculated that the statocyst/statolith complex may act as an organ of vibration detection of "hearing".

ABSTRACT

EVOLUTION AT THE OCTOPINE DEHYDROGENASE
LOCUS IN A LINEAR POPULATION OF THE FRESHWATER
SNAIL, *GONIOBASIS PROXIMA*: A TWO-YEAR REPORT

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The pleurocerid snail, *Goniobasis proxima*, is widespread in small streams draining the piedmont and mountains from Virginia to Georgia. The snail is not found in large rivers. In Naked Creek (a tributary of the Yadkin River in northwestern North Carolina) snail densities decrease from over 1000 per square meter near the stream head to less than 10 per square meter 5 km downstream. In May of 1979, nine sample sites separated by varying stream distances were selected on Naked Creek. Three comparison sites were selected on streams 500 meters to 10 km distant. Isozyme frequencies at three loci, octopine dehydrogenase, mannose-phosphate isomerase, and glucose-phosphate isomerase, were then determined in approximately 100 *G. proxima* from each of these 12 sites using starch gel electrophoresis. The three comparison sites were very different genetically from the 9 Naked Creek sites (considered together) and from each other. As distance from the 9 Naked Creek sites increased, genetic differences increased. Within the 9 Naked Creek sites, there was significant variance at the Odh locus. One abrupt change in gene frequency over 500 m corresponded to a culvert believed to impede snail migration upstream. During the summer of 1979, a local construction project generated silt that smoothed the culvert waterfall and thus temporarily removed the obstruction. By May of 1980, Odh gene frequencies across this 500 m stretch of Naked Creek had equilibrated. Studies will continue at Naked Creek, particularly focusing on the heterozygote deficiencies that may be promoted by the mobility and longevity of *G. proxima*.

ABSTRACT

GENETIC VARIATION AND PARTHENOGENESIS
IN *CAMPELOMA* (VIVIPARIDAE).

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Twenty-five isozymes were studied in populations of *Campeloma geniculum*, *C. floridense* and *C. limum* to determine the systematic relationships of these three snail species in the southeastern United States. Additional analyses of mothers and brooding young were conducted to determine the occurrence of parthenogenesis.

ABSTRACT

COMPARATIVE SHELL MORPHOMETRICS AND SOFT
ANATOMY IN DISJUNCT POPULATIONS OF *ELLIPTIO*
LANCEOLATA (LEA, 1828) COMPLEX

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Twenty nominate species have until recently been synony-

mized as *Elliptio lanceolata*. The taxonomy of this group has been confused by the reliance upon notoriously variable shell characters to distinguish species. Soft anatomy has been applied only superficially to aid species identification within the complex.

The purpose of our investigation was to examine variability and overlap in shell characters and to compare soft anatomy of individuals from two disjunct populations of the complex: *E. cf. fisheriana* (Lea, 1838) from the Little Pee Dee River and *E. lanceolata* - form cf. *producta* (Conrad, 1836) from the South Edisto River in South Carolina.

Specimens were dredged from both rivers, relaxed in Tri-caine and 2-Phenoxyethanol, and killed in a graded ethanol series. After sexing, using Ortmann's technique, specimens were retained in 70% "AGW". Counts of major annuli and a series of seventeen linear and angular measurements were taken from each pair of shells.

It was possible through Principal Component Analysis and Multiple Discriminant Analysis, using log-transformed data, to distinguish the two forms based on shell morphometrics. However, no single character was suitable for discrimination.

Soft anatomy provided a more reliable means of differentiation. Numbers of right anal and branchial papillae and of filaments and septa in the inner left gill were compared between populations. After staining with Wright's stain and counterstaining with Fast Green, both gill septa and filaments could be recognized and counted. The number of medial (superior) anal papillae, the total number of filaments, and the mean number of filaments per water tube differed significantly between populations. Additionally, the connection of the diaphragm to the posterior margins of the mantle differed in each population.

Such differences warrant recognition of the South Edisto population as a species distinct from *Elliptio cf. fisheriana* (Lea, 1838), however further study is necessary to determine its correct name.

ABSTRACT

KARYOTYPE VARIATION IN *CAMPELOMA*
(MESOGASTROPODA: VIVIPARIDAE) IN THE S.E. U.S.

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Dioecious and parthenogenetic populations of *Campeloma* were compared with respect to chromosome number and gross chromosomal morphology via the air-dried slide technique. The diploid chromosome number was 28 for all populations examined although endopolyploidy occurred in the digestive gland. Parthenogenetic populations differed from dioecious populations by several pericentric inversions.

ABSTRACT

THE CHANGING OHIO RIVER NAIAD FAUNA:
A COMPARISON OF SPECIES ASSOCIATED WITH EARLY
INDIAN MIDDENS AND CONTEMPORARY RESIDENT
SPECIES.

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The Ohio River has been radically modified, over the past

150 years, through the activities of man. Evidence from recent studies, based on shell middens associated with archaeological digs along the upper Ohio River, indicates a rich prehistoric naiaid faunal assemblage composed of at least 32 species. A recent survey of the upper Ohio River showed only 12 of the original 32 species still inhabiting that portion of the river.

ABSTRACT

SYSTEMATIC AFFINITIES OF *LEPYRIUM SHOWALTERI* (LEA), A FRESHWATER SNAIL FROM THE ALABAMA RIVER SYSTEM

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Lepyrium showalteri belongs to a monotypic genus that is endemic to the Alabama River System. The only currently known extant population is confined to the Little Cahaba River. Its peculiar neritoid shell shape is a special adaptation for existence in boulders in swift currents. *Lepyrium* is closely related to *Somatogyrus*, *Clappia*, and *Gillia*. The four genera comprise a monophyletic group for which the family-group taxon name LEPYRII (NAE) is available. This group is a tentatively assigned subfamily status within the HYDROBIIDAE because of (1) operculum simple, corneous, paucispiral, (2) central tooth of radula with basal cusps on reflected lateral angles, (3) central tooth with elongate mesocone and smaller ectocones, (4) female with a single genital opening in mantle cavity, (5) seminal receptacle enters oviduct posterior to bursa copulatrix duct, (6) males with a penis originating on right side of nape, (7) penis with a single duct, the vas deferens. The LEPYRIINAE differs from the HYDROBIINAE as follows: (A) foot broad, oblong ovate, (B) yellow pigment present on tentacles and body, (C) mantle collar without papillae or tentacles, (D) fecal pellets spiral, (E) lateral tooth of radula with a narrow lateral shaft, (F) a single small verticle seminal receptacle on primary oviduct along left side of albumen gland, (G) sperm enters via a spiral canal on ventral side of pallial oviduct, (H) ovary small, confined to right side of penultimate whorl of digestive gland, (I) penis simple, blade-like, without accessory lobes or papillae, (J) prostate confined posterior to mantle cavity, (K) testis forming a large mass overlying dorsal surface of digestive gland, overlapping prostate, and (L) seminal vesicle highly convoluted, appressed against gonadal lobes.

ABSTRACT

ATLANTIC APLYSIOMORPHA (GASTROPODA: OPISTHOBANCHIA) AND THEIR DISTRIBUTION

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Eight of the ten genera of Aplysiomorpha are represented in the Atlantic fauna, with only *Dolabella* and *Barnardaclesia* being absent. Twenty-four species have been recorded from the Atlantic as a whole and of these, eighteen have been reported from the western Atlantic. Seven of the species occur on both western and eastern sides of the Atlantic - *Aplysia brasiliana*, *A. dactylomela*, *A. juliana*, *A. parvula*, *Dolabrifera dolabrifera*, *Petalifera petalifera*, and *Bursatella leachi*.

It is known that food availability determines the local occurrence of opisthobranchs and if a species which can eat a variety

of foods is not present at all latitudes then their must be other factors limiting its occurrence. Temperature and other physical factors such as salinity limit geographical range. Species found in cold waters tend to be adversely affected above 18°C while species found in warm tropical waters can tolerate up to 30°C. Two other factors limit the spread of populations - the land on one side and the deep oceanic region on the other. More recently man has played a part in distribution with species travelling on boat bottoms and in the ballast water of tankers.

Little is known about the movement of aplysiids during their annual life history. Attempts to study populations so far report of their sudden disappearances. It is thought that the species which occur on both sides of the Atlantic are distributed by their larval stages.

ABSTRACT

SHELL AND RADULAR VARIABILITY IN *UTRICULA STRA CANALICULATA* (SAY, 1826) (GASTROPODA: SCAPHANDRIDAE)

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Quantitative examination of shell and radular characters of *Utriculostra canaliculata* (= *Acteocina candei* (Orbigny, 1841)) was conducted on material from the Indian River lagoon, in central eastern Florida. Particular attention was paid to features used by Wells and Wells (1962, *Nautilus* 75(3): 87-93) to distinguish *A. candei* from "*Retusa*" *canaliculata*: percent spire height, spire angle, degree of protoconch protrusion, and characters of the lateral and rachidian teeth. Other characters noted were gizzard plate morphology and number of radular rows. All characters examined were extremely variable within and between populations, supporting Marcus' (1977, *Jour. Moll. Stud.*, Suppl. No. 2: 1-35) placement of *A. candei* in synonymy with *U. canaliculata*. With the exception of the degree of protoconch protrusion, all characters showed a relationship with shell length. Assuming that shell length is an indication of age, these data suggest that the shell and radular variation in *U. canaliculata* is ontogenetic, with the "*candei*" form developing into "*canaliculata*".

ABSTRACT

COMMENTS ON CHITONS (MOLLUSCA: POLYPLACOPHORA) OF THE BAHAMA ISLANDS

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Fourteen species of polyplacophorans [*Ceratozona squalida* (C.B. Adams, 1845), *Ischnochiton erythronotus* (C.B. Adams, 1845), *Stenoplax limaciformis* (Sowerby, 1832), *Callistochiton shuttleworthianus* Pilsbry, 1893, *Chiton marmoratus* Gmelin, 1791, *C. squamosus* Linné, 1764, *C. tuberculatus* Linné, 1758, *C. viridis* Spengler, 1797, *Acanthopleura granulata* (Gmelin, 1791), *Toncia schrammi* (Shuttleworth, 1856),

Acanthochitona hemphilli (Pilsbry, 1893), *A. pygmaea* (Pilsbry, 1893), *A. spiculosa* (Reeve, 1847), and *Choneplax lata* (Guilding, 1829)] have been reported from the Bahama Islands between 1867 and 1978. Recent Bahamian collections have revealed *Lepidochitona liozonis* (Dall and Simpson, 1901), *Ischnochiton hartmeyer* Thiele, 1910, *I. striolatus* (Gray, 1828), *Acanthochitona balesae* Abbott, 1954, *Cryptoconchus floridanus* (Dall, 1889), single undescribed species of *Chaetopleura*, *Ischnochiton*, and *Stenoplax*, and two undescribed species of *Acanthochitona*, increasing the known number of species to 24. Intensive collecting at Grand Bahama, where 22 species are known, indicates *Chiton marmoratus* and *C. squamosus* may not occur there, perhaps due to environmental differences between that leeward island and more windward Bahamian islands where both species are common. Numbers of species known from other major islands of the northern Bahamas are: Abaco (12), Andros (8), Bimini (9), Eleuthera (9), and New Providence (7). Except for the highly conspicuous *Acanthopleura granulata*, virtually no chiton species are known from the relatively remote southern Bahamas, almost certainly a reflection of low collecting effort.

Twenty-nine species of shallow water (<50 m depth) chitons occur either in tropical south Florida (southeast coast, Florida Keys, and Dry Tortugas) or in the Bahamas, but only 17 species (59%) are known from both areas. *Calloplax janeirensis* (Gray, 1828), a species common from Brazil to south Florida, has been conspicuously absent from Bahamian collections. Although additional collecting may increase the number of species shared by both areas, some differences will persist due to absence of environmental situations suitable for such species as *Chiton marmoratus*, *C. squamosus*, *C. viridis*, *Acanthochitona spiculosa*, and *Choneplax lata* in south Florida.

ABSTRACT

PRESENCE OF THE PARASITIC GASTROPOD
MELANELLA TOWNSENDI IN THE HOLOTHURIAN
ISOSTICHOPUS FUSCUS.

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The parasitic relationship between *Melanella townsendi* and its host *Isostichopus fuscus* is reported for the first time. Parasites were encountered on the dorsal surface and near the buccal ring of more than 95% of the holothurians examined. Parasitism does not affect the holothurians' ability to assimilate organic detritus, its preferred food.

ABSTRACT

GROWTH, DISPERSAL AND METAMORPHOSIS IN LARVAE
OF HAWAIIAN *CONUS*

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Laboratory rearing studies on the larvae of eight species of *Conus* reveal species-specific differences in planktonic growth rate and pelagic period. These differences are related to variation in egg size. Larvae developing from small eggs show slow planktonic growth and spend long periods of time in the plankton. Consequently, these species have high dispersal potential.

Larvae developing from large eggs grow quickly, have short planktonic periods and low dispersal potential. In the species examined, planktonic periods ranged from 50 days for *Conus lividus* to zero days for the lecithotrophic larvae of *C. pen-naceus*.

In the laboratory, larvae were reared on 55 liter fiberglass tanks on a diet of *Isochrysis galbana* and *Phaeodactylum tricornutum*. *Conus* larvae will metamorphose on any surface with a biological film and therefore do not show site-specificity at settling. Just after metamorphosis, larvae of *Conus* undergo a sudden increase in dry weight which is not paralleled by a comparable increase in shell length. It appears that this weight increase results from calcification of the larval shell. It is suggested that a light uncalcified shell may be advantageous to the pelagic larva, while a heavily calcified shell is better suited to the rigors of the benthic environment.

ABSTRACT

INITIAL RESULTS OF A SUSPENDED CULTURE OF
CRASSOSTREA VIRGINICA IN SOUTHEASTERN
LOUISIANA WATERS

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Techniques of the oyster fishing industry in the U.S. remain on a primitive, gathering level. Harvests depend on exploiting the natural productivity of the waters rather than control over a self-sustaining crop. The purpose of this study is to determine the growth rate and mortality of oysters grown in a suspended culture system, versus the growth rate and mortality of conventional bottom cultures.

ABSTRACT

A PENIS-LIKE STRUCTURE IN FEMALE *NUCELLA*
LAPILLUS FROM NEW ENGLAND

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Seven New England populations of the gastropod *Nucella lapillus*, were sampled between May, 1980 and May, 1981 to obtain material for a parasite study. During the course of this investigation a number of females was found to possess a penis-like structure originating from behind the right tentacle.

Approximately 2000 females were examined; 328 (16.5%) had penises. All of these individuals came from populations located south of Cape Cod (Block, Is., RI., Pt. Judith (I) & (II), RI., and Avery Pt., CT.), while females from northern populations (Manomet, MA., Pemaquid Pt., ME., and Eastport, ME.) were lacking them. The Pt. Judith (II) site was studied most thoroughly and had a high and fairly stable seasonal incidence of females with penises (Dec '80, 73.2%; Feb '81, 77.4%; Apr '81, 77.5%; May '81, 82.8%).

Penises found in female snails originated from the same site as those of their male counterparts but differed in size and shape. Mean penial length of 50 female ($X = 1.94 \pm 0.57$) and 50 male ($X = 4.53 \pm 0.66$) Pt. Judith (II) snails was significantly different at $P < 0.001$.

The gross morphology of the remainder of the reproductive tract of females with penises was entirely female. Snails could be sexed readily by the appearance of the gonads: granular for females and agranular for males. This was confirmed by microscopical examinations of direct gonad smears, which revealed a 1:1 sex ratio in Pt. Judith and Avery Pt. snails.

Statistical analysis revealed significant positive correlations between females possessing penises with shell height and size of penis with shell height for both sexes. Parasitism was not significantly correlated with any variable.

Among the possible explanations for the occurrence of penises in female snails are: exposure to high water temperatures during critical developmental stages; exposure to pollutants, as suggested by Smith (J. Moll. Stud. 46:247-256. 1980); genetic differences; or a combination of factors.

ABSTRACT

THE DISTRIBUTION AND BIOLOGY OF PTEROPODS FROM THE BAY OF FUNDY REGION, CANADA (GASTROPODA: OPISTHOBRANCHIA).

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Quantitative horizontal and vertical distributions of two species of pteropods, the thecosome, *Limacina retroversa* (Fleming) and the gymnosome *Clione limacina* (Phipps) were studied from 116 stations covering the entire Bay of Fundy and adjacent waters in spring, summer and fall from 1979 to 1981.

L. retroversa was found to be abundant within the bay, having a maximum density of 14,100 below 1 m² in July 1979 and *C. limacina* was found to be common with a maximum density of 203 below 1 m² at the same time. Both species were found to be concentrated at the mouth of the bay in spring, showed a further influx into the upper portions in summer and a recession out of the bay proper in fall. It would appear that these pteropod species are not endemic to the Bay of Fundy region.

Vertical distributional studies indicated that both species display a reverse vertical migration being concentrated at the surface at midday.

ABSTRACT

THE STAR-SNAIL CONNECTION

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In 1822 a Munich astronomer published a drawing of a lunar formation named Snail Mountain. The polygonal form of features surrounding it, which are now attributed to a lava flow, led him to describe it as the ruins of a fortress guarding an ancient city.

Faint stars near the end of the north circumpolar constellation, Draco, depict a snail crawling on the dragon. Venus, goddess and planet, was born of foam and floated ashore on a scallop shell. Polynesians used a combination of star heights seen from islands and stick charts of bamboo and cowrie shells in navigation. Squid, which are attracted by moonlight, are lured by artificial light.

A limestone quarry in Sweden has yielded a 463 million year old meteorite which struck and killed a shelled cephalopod.

Replacement of minerals in the meteorite makes it as much a fossil as the cephalopod.

ABSTRACT

NEW OCCURRENCES OF MARINE MOLLUSKS FROM AMAPÁ, NORTH BRASIL

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For 30 days in February of 1981, the junior authors of this study made some dredgings and collectings in shrimp nets on board of the ships "Seiwa-2", "Nischin-19" and "Npq. Rio-baldo", in the region between the mouth of the Para River and the Orange Cap (Amapá), in depths of 30 to 100 meters.

During the work, the salinity varied from 23 to 30 grammes/liter, the temperature on the surface of the water was 28 to 30°C and for the first time the following species of mollusks were collected at Amapá on a muddy bottom:

Calyptrea centralis (Conrad)
Strombus costatus Gmelin
Strombus raninus Gmelin
Voluta ebraea Linnaeus
Conus beddomei Sowerby
Hydatina vesicaria Solander
Lyropecten nodosus Linnaeus
Divalinga quadrisulcata (Orbigny)
Arcinella arcinella (Linnaeus)
Chione intapurpurea (Conrad)
Tellina trinitatis Tomlin
Tellina punicea Born

The new record for Brasil is *Cymatium krebsi* Mörch, 1877.

ABSTRACT

ON THE POSSIBLE DERIVATION OF THE FISSURELLIDAE FROM THE BELLEROPHONTACEA

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Golikov and Starobogatov's (1975) theory that the Paleozoic bellerophontaceans gave rise to the Mesozoic-appearing Fissurellidae is considered. Fissurellids could have so been derived in a process of pedomorphosis — sexual maturity attained before the development of adult characters — in this case the coiled shell. This is supported by the following arguments: 1) Fissurellid anatomy differs in major ways from that of other dibranchiate gastropods, particularly in the nearly vestigial condition of the left kidney; this anatomy is probably shared with the coiled predecessor. 2) The similar shell structure of crossed-lamellar aragonite shared by fissurellids and bellerophontaceans suggests common ancestry. 3) Contrary to previous accounts, there is no several-whorled, orthostrophically coiled phase in fissurellid ontogeny. The suppression of adult coiling allowed the inherent asymmetry of torsion to have an immediate effect, producing the varying degrees of postprotoconch asymmetry expressed in the Fissurellidae. 4) The fissurellid postprotoconch shows whorl overlap (as does the mature

bellerophontacean), brought about by delayed development of the columellar lip, suggesting that fissurellid ontogeny includes a bellerophont stage. 5) The internally directed, hook-shaped process of the fissurellid muscle scar may be homologous with the "oblique transdorsal element" of the bellerophontacean muscle scar. 6) The morphology of shell slits in fissurellids and bellerophontaceans is similar. 7) Some bellerophontaceans — those not having the tangential apertures of shell clamping gastropods — must have had internal shells, yet shell sculpture is not obliterated. Some fissurellids also have sculptured internal shells. The same structure of the mantle edge, in which shells are enveloped by the middle fold of the mantle, could account for this capacity in both groups.

Necessary steps in the derivation of the Fissurellidae are: suppression of coiling and loss of the columella, migration of the paired shell muscles and their posterior union to form the horse-shoe-shaped muscle, shortening of the mantle cavity, and addition of short afferent membranes for ctenidial support. Just as the Haliotidae are limpet derivatives of the Pleurotomariacea, the Fissurellidae are the logical limpet derivatives of the Bellerophontacea. The changes required for the derivation of the haliotids are the same; the fissurellids have carried the process further in forming a horseshoe-shaped muscle.

Paleontologists have recently shown that some Paleozoic bellerophonti-form mollusks were probably untorted; some paleontologists maintain that their symmetry indicates that all were untorted. The likelihood that the fissurellids were derived from a bellerophontacean stock lends support to the theory that the Bellerophontacea, except for the so-called "cyclomyan monoplacophorans," were torted gastropods. Here, however, they are considered neither the earliest nor the most primitive gastropods.

ABSTRACT

SUMMARY OF RESTRICTED AND DECLINING NON-MARINE MOLLUSCS OF TEXAS

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A list of non-marine molluscs which have restricted and/or declining geographical ranges in Texas has been compiled. A total of 64 gastropods (55 terrestrial and 9 aquatic species) and 13 unionid pelecypods are currently on the list. These species are geographically concentrated in eastern Texas, the Eastern Caprock Escarpment, Hill Country, Basin mountain ranges, Chisos Mountains, Guadalupe Mountains, Franklin Mountains and the Lowe. Rio Grande Valley. Habitat destruction is the most common cause of populational declines but water quality alterations and direct exploitation are also involved.

SYMPOSIUM: PROCEEDINGS OF THE SECOND AMERICAN MALACOLOGICAL UNION SYMPOSIUM ON THE ENDANGERED MOLLUSKS OF NORTH AMERICA

(organized and edited by Dr. Arthur H. Clarke)

INTRODUCTION

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In 1968, the American Malacological Union, alarmed by frequent catastrophes to our fauna, convened a symposium designed to provide the first assessment of the status of endangerment of the mollusks of North America. The proceedings of that symposium were published in *Malacologia* (vol. 10, pp. 1-56). The proceedings contain annotated lists of species which many of the leading malacologists in this continent believed to be endangered. 45 species of land snails, 185 species of freshwater mollusks (mostly Unionidae), 1 marine species (*Algamorda newcombiana* (Hemphill), a littorinid), and an undetermined number of brackish-water snails (Hydrobiidae) yet to be described, were enumerated. The symposium also showed that little detailed information was available about the distribution, population size, or life history of any presumably endangered species and it thereby pointed out some of the important questions to be addressed by future research.

The excellent papers presented during this, the second AMU Symposium on the Endangered Mollusks of North America, illustrate much of the progress which has been achieved since 1970. The most significant event related to the conservation of mollusks was federal enactment of the Endangered Species Act in 1973 (see the paper by Chambers). Through the activities of the office of Endangered Species, which was created to administer the Act, 25 species and subspecies of freshwater mussels, all species of *Achatinella*, and 8 other species of terrestrial snails have now been placed on the federal Endangered Species List. Other federal agencies have also responded to the Act by establishing extensive and highly significant new research programs (papers by Jenkinson and Miller). Several of the states have also undertaken activities which effectively promote the preservation of molluscan faunas (papers by Buchanan, Call and Parmalee, and Jokinen and Pondick). Research by scientists who have long been dedicated to molluscan conservation have continued to produce important results (other papers in this symposium).

Given this substantial activity, one might conclude that the molluscan fauna of North America was in a relatively secure condition. That, unfortunately, is far from true. The current literature is replete with documented cases of continual decline of the precious mussel faunas of our rivers. The mussel fauna of the Green River in Kentucky, for example, which until 10 years ago was one of the most diverse in North America, has now been reduced by controlled temperature reduction and siltation to about 1/3 of its previous diversity, and appears to be getting worse. Numerous species which are surely endangered cannot be officially considered for possible inclusion on the Endangered Species List because funds for that purpose are lacking. Other governmental support for conservation efforts also appears to be diminishing.

The situation is not without hope, however. Concerned biologists, perhaps inspired by some of the contributions to this symposium, will continue to do useful research. The AMU, I am sure, will also continue to support this worthy cause. If we fail to do so, no other organization is likely to assume the responsibility, and very many of our unique molluscan species may soon perish from the earth.

THE DISCOVERY OF EXTANT POPULATIONS OF
ALASMIDONTA ATROPURPUREA (RAFINESQUE)
 (BIVALVA: UNIONIDAE)
 IN THE CUMBERLAND RIVER BASIN

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ABSTRACT

Extant populations of the Cumberland River endemic, *Alasmidonta atropurpurea*, were discovered in 1979 and 1980 in the Cumberland River drainage in Kentucky and Tennessee. This naiad was found in medium sized streams of moderate gradient and high water quality. It apparently prefers habitats with boulder to cobble substrate, low velocity and depths of 0.3 to 0.5 meters. *Alasmidonta atropurpurea* comprised the major component of the unionid fauna at all observed localities.

The poorly known naiad *Alasmidonta atropurpurea* is endemic to the upper and middle Cumberland River basin. The recent discovery of existing viable populations in Kentucky and Tennessee provide needed taxonomic clarification and ecological information.

In 1979 and 1980, extant populations of *A. atropurpurea* were discovered in the upper Cumberland River drainage in Kentucky and Tennessee. The only viable Kentucky population observed this century was reported by Harker et al. (1980) from Marsh Creek, a fifth order McCreary County stream located above Cumberland Falls. They also reported a single valve from Rock Creek in McCreary County. Several unsuccessful attempts have been made to locate additional specimens at this location. The two Tennessee populations are located in Clear Fork River on the Morgan/Fentress County line and Whiteoak Creek in Morgan County (Figure 1). In September 1978 a single freshly-dead specimen was taken by Dr. and Mrs. Arthur Bogan from the Collins River near Mount Olive, Grundy County, Tennessee (Clarke 1981). Additional unsuccessful attempts were made to locate a viable population at this location. Previous mussel surveys of all or portions of the Cumberland River drainage, conducted by Williamson (1905), Wilson and Clark (1914), Shoup and Peyton (1940), Neel and Allen (1964), Stansbery (1969), Blankenship and Crockett (1972), the Tennessee Valley Authority (1976) and Parmalee et al. (1980), failed to yield specimens of *A. atropurpurea*.

All three of the aforementioned locations support only a small number of unionid species, although some such as *A. atropurpurea* and *Elliptio dilatata* are abundant. In Marsh Creek *A. atropurpurea* was taken in association with *Alasmidonta viridis*, *E. dilatata*, *Actinonaias pectorosa*, *Lampsilis ovata ventricosa* and *L. fasciola*. The occurrence of *A. atropurpurea* in Marsh Creek is of added significance since it constitutes an addition to the meager mussel fauna known from the Cumberland River above Cumberland Falls. At the Tennessee locations *A. atropurpurea* was found with *Lasmigona costata*, *E. dilatata*, *Villosa iris*, *Lampsilis ovata* and *L. fasciola*. Shells of *A. atropurpurea* were the most numerous of all the species represented at each location. At the time these streams were collected in August 1980, the water levels were low and large numbers of shells were found scattered over the bottom, on boulders, and

along the banks, the mussels apparently having been taken by muskrats. Measurements (anterior - posterior length: mm) were taken of the 20 largest specimens collected in the Clear Fork River and Whiteoak Creek; the observed range was 70.5 - 92.0 with a mean of 76.8.

The type specimen of *A. atropurpurea* described by Rafinesque (1831) was apparently lost (Clarke 1981), thus leading to later taxonomic uncertainty. Simpson (1914) listed this naiad as an unfigured and indeterminate species. According to Ortmann and Walker (1922), Frieson considered this naiad equivalent to *A. raveneliana* but Ortmann (1918) and Ortmann and Walker (1922) believed that *A. atropurpurea* was a form of *A. marginata*. However, the latter authors noted that the correct identification of *A. atropurpurea* specimens was not assured and they considered it as an unidentified form. Morrison (1969) also considered *A. atropurpurea* synonymous with *A. raveneliana*. These taxonomic problems were probably due to the paucity of specimens present in museum collections. The species description and remarks by Clarke (1981) and his selection of a neotype have clarified the taxonomic status of this species.

Collection data and observations indicate that *A. atropurpurea* prefers medium sized, moderate gradient, high quality streams typical of the Cumberland Plateau. It lives at a variety of depths ranging from 0.075 to 1.5 m but was most commonly observed at depths of 0.3 to 0.5 m. This naiad occupies various current regimes but usually inhabits areas with near zero flow (0.1 m/sec.). *A. atropurpurea* typically occupies the interstitial spaces within cobble and/or boulder substrate; it is usually

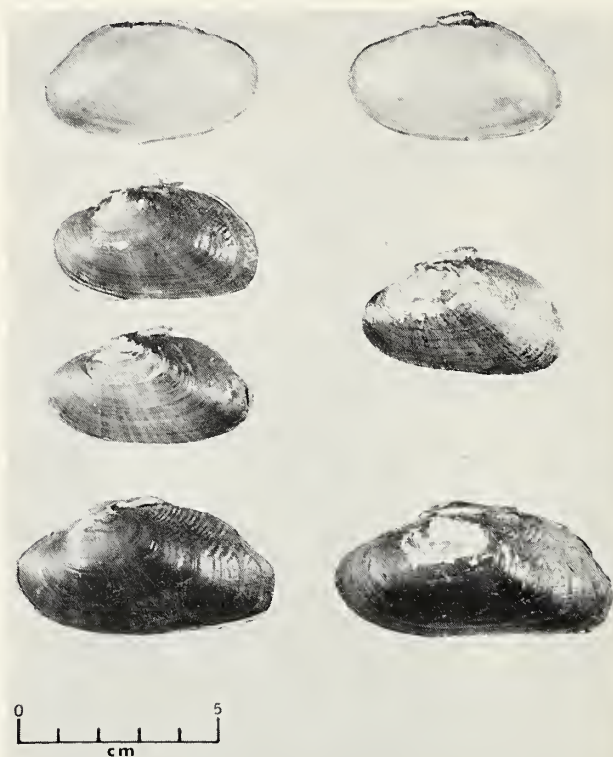


Figure 1. Examples of *Alasmidonta atropurpurea* from Clear Fork River and Whiteoak Creek, Morgan County, Tennessee.

found buried in a sand/gravel/mud mixture from 1/2 to 2/3 of its length in a position perpendicular to the substrate.

The continued survival of *A. atropurpurea* is uncertain as the streams in this portion of the Cumberland Plateau are continuously being decimated by coal mining operations. The Marsh Creek population of *A. atropurpurea* is being threatened by extensive strip mining operations which are taking place in the headwaters. Mining operations are also occurring throughout a large portion of the Big South Fork of the Cumberland River drainage in Tennessee.

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THE DISTRIBUTION AND HABITAT OF THE CURTIS' PEARLY MUSSEL, *EPIOBLASMA FLORENTINA CURTISI* (UTTERBACK 1915) IN SOUTHEASTERN MISSOURI.

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ABSTRACT

The distribution of *Epioblasma florentina curtisi* has never been well known. During the past fifteen years it has been reported only from Missouri at one site in Castor River, two sites on upper Black River, one site on upper Cane Creek, a tributary to Black River, and three sites on upper Little Black River. This species was also reported from two sites on upper White River during the early 1900's, but those sites are now impounded. *Epioblasma florentina curtisi* occurs in portions of Ozark streams which serve as transition areas between headwater and lowland stream reaches. This species has been found in slow current in or near riffles, in 4 to 22 inches of water, in a predominantly gravel substrate. Studies of the distribution, abundance, habitat requirements, and status of *Epioblasma florentina curtisi* in Missouri are continuing.

A REVIEW OF THE CURRENT STATUS OF THE UNIONID MOLLUSKS OF THE MISSISSIPPI AND ST. LAWRENCE RIVER SYSTEMS (BIVALVIA: UNIONACEA).

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ABSTRACT

The study of selected stream sites and a review of unionid records of the Ohio State University Museum of Zoology and those of some other institutions reveal an apparent decline in both numbers and species of unionids. These data indicate that many species are endangered in some degree and that some are apparently extinct or nearly so.

ENDANGERED OR THREATENED AQUATIC MOLLUSKS OF THE TENNESSEE RIVER SYSTEM

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It is not customary to begin a brief scientific paper with an

acknowledgement; however, this is not a typical single author paper. A number of Tennessee Valley Authority (TVA) biologists who study mollusks have pooled their recent data and observations to form this composite list of proposed endangered or threatened species. We have chosen this format to shorten presentation space and time for this symposium and to facilitate ongoing Agency evaluation studies. Contributors to this paper are: Steven A. Ahlstedt, Charles Gooch, Billy G. Isom, John J. Jenkinson, Leroy M. Koch, W. Jeffrey Pardue, Lynn B. Starnes and Donald C. Wade. The opinions expressed here are those of the contributors and do not necessarily represent the views or policies of our employer. Any errors in the presentation of this material are the fault of the compiler.

While TVA has funded mollusk studies throughout its 50 year history, during the last ten years (1971-1981) Agency biologists and our contractors have conducted extensive mollusk investigations all across the Tennessee River system. Early in this decade the focus of our work was primarily on the commercially important freshwater mussel species of the larger rivers. After the Endangered Species Act became a Federal law and some resident freshwater mussels and pleurocerid snails were proposed or listed as threatened or endangered, our focus shifted in large part to these species, many of which occur in smaller streams. The recent addition of the Cumberlandian Mollusk Conservation program to our activities (Jenkinson, 1981) has added considerable support to these small-stream studies.

Since 1971 we or our consultants have examined freshwater mussel or snail populations in approximately 1000 miles of Tennessee Valley rivers and streams. Over 800 miles of this survey effort involved scuba or snorkel diving and over 650 miles of our study was conducted in the 1979 and 1980 field seasons. While these numbers may be impressive, the 1000 miles examined constitutes only 2.4 percent of the total length of all streams in the Tennessee River system (42,000 miles). Included in this figure are major surveys of the Tennessee, Powell, Clinch, lower Nolichucky, Paint Rock, Elk, upper Duck and upper Buffalo rivers.

In addition to information on the presence and abundance of species, these surveys have given us the opportunity to observe the current status of a long list of present and former mollusk habitats. We have observed impounded reaches and altered tailwaters below impoundments where few or no mollusks exist; we have sampled reproducing populations from current swept gravel bars that are covered by 15-30 feet of impounded water; and we have sampled classic habitats that retain much of their original diversity.

We now know that a great variety of habitats suitable for mollusk populations persists in this watershed. Long reaches of near-original stream conditions remain, although they are as rare in the Tennessee Valley as they are elsewhere in eastern North America. Many river reaches have been impounded providing extensive habitats for a few species. Downstream from the dams are a variety of habitat types, some of which already support surprisingly diverse faunas. Other reaches may become suitable habitats as proposed pollution abatement and habitat improvement programs are implemented.

In preparing the following list of mollusk species that we feel should be considered threatened or endangered, we have attempted to adhere to three criteria:

- 1) We have restricted our attention to those mollusk species that have been reported from the Tennessee River or its tributaries. Although several of us have

knowledge and opinions about species that do not occur in this watershed, we felt our expertise is strongest in dealing with the local fauna.

- 2) We have chosen to restrict our list to species that fit the definitions of "endangered species" and "threatened species" in the Federal Endangered Species Act. In both cases these definitions are tied to threats to a species throughout "all or a significant portion of its range." We also have chosen not to suggest whether a particular species ought to be considered threatened or endangered. That task is the responsibility of the U.S. Fish and Wildlife Service and both categories enjoy considerable protection under the law.
- 3) The last criterion we applied was that the listing of each species must be supported by our majority opinion. Like any other group of malacologists, we occasionally disagree on individual issues.

The chief result of our deliberations is the following annotated list of twelve species we feel are endangered or threatened in the Tennessee River system. All of these species are endemic to this watershed and, therefore, we have some confidence in recommending them for one or the other of these categories.

Bivalves

Conradilla caelata (Conrad, 1834) [?= *Lemiox rimosus* Rafinesque, 1831]: only abundant in the Duck River.

Epioblasma [= "Dysnomia" = "Plagiola"] *turgidula* (Lea, 1858): last found in the upper Duck River at sites now inundated by Normandy Dam; may be extinct.

Fusconaia cuneolus (Lea, 1840): widely distributed in tributary streams; most abundant in the Clinch River; often confused with similar species.

Fusconaia edgariana (Lea, 1840) [= *F. cor* (Conrad, 1834)]?: widely distributed in tributary streams; most abundant in the upper North Fork Holston River.

Lampsilis virescens (Lea, 1858): now apparently restricted to the Paint Rock River system.

Lasmigona holstonia (Lea, 1838)? : a headwaters species that is rare in our collections. We may not be collecting in streams small enough to locate it.

Lexingtonia dolabelloides (Lea, 1840): most abundant in the Duck River.

Quadrula intermedia (Conrad, 1836): most abundant in the Powell River.

Quadrula sparsa (Lea, 1841) (a subspecies or form of *Q. metanevra*?): present only in the Powell River.

Toxolasma cylindrella (Lea, 1868): apparently now restricted to the Paint Rock River system.

Villosa perpurpurea (Lea, 1861) [? = *V. trabalis* (Conrad, 1834)]?: only abundant in Copper Creek (Clinch River drainage).

Gastropod

Io fluvialis (Lea, 1831): reduced to populations in the Powell, Clinch and Nolichucky rivers.

During our discussions we also identified the following 25 species which although not restricted to this watershed, appear to be declining in our streams. Each of these species should be added to the Federal list only if it is being impacted throughout "all of a significant portion of its range."

Bivalves

Alasmidonta viridis (Rafinesque, 1820) (per Clarke, 1981): a widespread species not present in our recent collections.

Cyprogenia irrorata (Lea, 1830) [= *C. stegaria* (Rafinesque, 1820)?]: an Ohioan species, declining in our streams.

Dromus dromas (Lea, 1834): a Cumberlandian species, now in the Powell, Clinch, Tennessee (one site), and Cumberland rivers.

Epioblasma brevidens (Lea, 1831) [= *E. interrupta* (Rafinesque, 1820)?]: a Cumberlandian species, declining in some of our streams.

Epioblasma capsaeformis (Lea, 1834): a Cumberlandian species, declining in our streams.

Epioblasma florentina florentina (Lea, 1857),

Epioblasma haysiana (Lea, 1834),

Epioblasma lenior (Lea, 1834),

Epioblasma lewisi (Walker, 1910),

Epioblasma torulosa gubernaculum (Reeve, 1865),

Epioblasma walkeri (Wilson and Clark, 1914): this and the preceding 5 species are all representatives of a larger group of Cumberlandian forms that may well be extinct; none of these forms is represented by living or fresh specimens in our recent collections.

Epioblasma sulcata sulcata (Lea, 1829): originally present in the lower Tennessee; now only known from the impounded Cumberland River where it does not appear to be reproducing.

Epioblasma torulosa torulosa (Rafinesque, 1820): a subspecies of the largest Ohio basin rivers not found by us in the Tennessee River; may be extinct.

Hemistena lata (Rafinesque, 1820): a widespread species that seems to be becoming increasingly rare in our streams.

Leptodea leptodon (Rafinesque, 1820): a widespread species that has not been found recently in the Tennessee River system.

Obovaria retusa (Lamarck, 1819): an Ohioan species that is becoming increasingly rare in the lower Tennessee River.

Pegias fabula (Lea, 1838): a widespread species not represented in any of our recent Tennessee River system collections.

Plethobasus cicatricosus (Say, 1829): an Ohioan species represented in our collections by a single specimen from the lower Tennessee River; nearly extinct.

Plethobasus cooperianus (Lea, 1834) [= *P. striatus* (Rafinesque, 1820)]: an Ohioan species rare, but still present in the Tennessee and Cumberland rivers.

Pleurobema clava (Lamarck, 1819): an Ohioan species only rarely found in the lower Tennessee River.

Pleurobema oviforme (Conrad, 1834): a Cumberlandian species which may be declining in our streams.

Pleurobema plenum (Lea, 1840): a widespread species (or form?) rarely distinguished from other members of the *P. cordatum* complex.

Simpsoniconcha [= *Simpsonaias*?] *ambigia* (Say, 1825) and *Villosa fabalis* (Lea, 1831): both widespread species that have not been found in any of our recent collections.

Gastropod

Lithasia armigera armigera (Say, 1821): in the Tennessee River this subspecies (form ?) has a more restricted habitat than the other species (forms ?) present.

One freshwater mussel species presently considered en-

dangered on the Federal list purposely has not been included here. Our surveys have located specimens of *Lampsilis orbiculata* in most of the tailwater reaches of the mainstem Tennessee River dams and in the 30 mile reach of the Cumberland River that we have examined. One of our contributors (Koch) has accumulated age and growth data on a population of *L. orbiculata* as sampled by commercial mussel fishermen and has documented continuing reproduction for the last 20 years. Our opinion (as yet not completely substantiated by field data) is that *L. orbiculata* remains the widely distributed, uncommon-to-rare species that it always has been. We see no threat to the continued existence of this species and, for that reason, have chosen not to suggest it for inclusion.

A final comment is required concerning the taxonomic coverage of this list. All of the species we have discussed are members of the bivalve superfamily Unionacea or the gastropod genera *Io* and *Lithasia* (= *Pleurocera* to some). Other groups of native aquatic mollusks have received little of our attention because they are not of commercial importance or because they have not been the subjects of Endangered Species Act issues. We are keenly aware that there may be endangered or threatened species in these other taxa; however, we have not had the occasion or the means to study them in any detail.

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ENDANGERED MOLLUSK STUDIES AT THE US ARMY
ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

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Vicksburg, MS 39180

ABSTRACT

The U.S. Army Engineer Waterways Experiment Station is working on a two-year project, funded by the Office, Chief of Engineers, to collect information on sampling methodologies, biological and ecological requirements, and habitat creation, for the federally-listed endangered mollusks. Information developed from this study will assist Corps of Engineers district biologists working with impact analysis, permit actions and environmental assessments.

INTRODUCTION

The Endangered Mollusk Study is a two-year project funded by the Office, Chief of Engineers, as part of the Environment Impact Research Program (EIRP). This study was designed to provide assistance to federal biologists involved with impact assessments, permit action, endangered species coordination, and directing contractor studies involved with endangered mollusks. This study has three major objectives:

- a. To collect information on sampling techniques for

freshwater mollusks. This will apply not only to the federally-listed species, but also the non-listed organisms. The work on sampling techniques has been subdivided into two tasks. The first task is concerned with methods for the design, construction, and use of various types of mollusk sampling equipment. Included will be information on the applicability of various gear types in different conditions. The other task is to provide techniques for determining adequate sample size and number of samples necessary to satisfy certain objectives. The first task will yield material useful only for freshwater bivalves; the second task will provide information applicable to other benthic surveys.

b. To collect and organize biological and ecological data on the federally-listed endangered mollusks. This includes data on range, life history, ecological requirements, and identifying features.

c. To analyze techniques used to relocate or create habitat for mollusks. Information developed under this objective will relate to endangered and non-endangered mollusks.

SAMPLING FOR MOLLUSKS

At the WES our work has been directed towards construction and testing of various methods for collecting freshwater mollusks. This includes the brail, brail hooks, an assortment of rakes, different sizes of quadrant samplers and plexiglass "see through" buckets.

Methods and equipment are based upon personal experience and information contained in Bumgarner (1980), Fuller (1978), Brice and Lewis (1979), Jacobson (1974), Starrett (1971), Parmalee (1967), Isom (1980), and Coker (1919). Brail hooks, while made from inexpensive wire, are time-consuming although easy to make. We have experimented with different sizes of wire, types of wood and hardware and will provide suggestions on the best type of material to use in a particular area (Figures 1-4). The brail, when compared with a diver using SCUBA and a quadrant sampler is less than 1% efficient. However, the brail has utility in deep rivers for preliminary sampling.

Determining the proper number and size of samples required is a primary consideration in almost every field survey. This is particularly true with organisms that are very uncommon and found in a habitat that is difficult to see and often hard to sample. A review of the literature on bivalves indicates that the

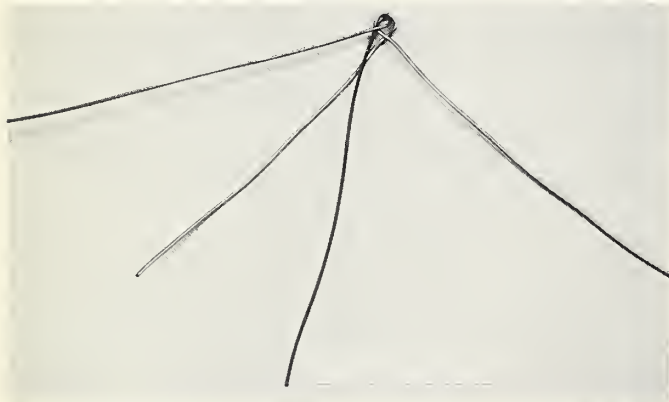


Figure 1. Construction of a brail hook. Two looped wires (#26 Music Wire) will be brought together to form the body of the hook.

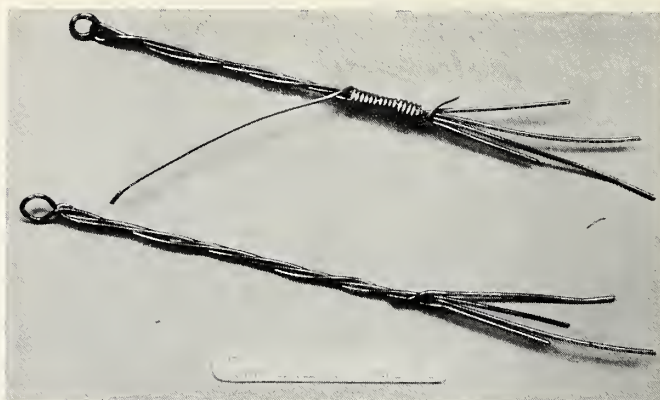


Figure 2. Partially constructed brail hooks.

majority of the work has been qualitative and related more to taxonomic or distribution problems than population densities. This work has been designed to answer some of the questions concerning the proper number and size of samples necessary to meet study objectives. Mere presence or absence of a particular taxon is no longer all the information needed to perform impact analyses. The investigator must be prepared to indicate numbers and provide appropriate confidence intervals.

The only quantitative methods for bivalves involve collecting all the organisms within a specific area of the habitat under study. This can be done with a grab sample (ponar, shipek, etc.) or by delineating a one or half meter square area and collecting all the animals that lie within the confines of the quadrant. If the organisms are not uniformly distributed, chance placement of the device usually yields markedly different results for each sample. To assist in determining how many and what size of sample would be adequate in a particular area, we have developed a computer program to simulate a benthic community. A program, written in FORTRAN, can create any type of distribution pattern (random, clumped, uniform) at a predetermined density. Another program lays a grid over this habitat and takes any number of random samples from the area. These two programs will enable an individual to become acquainted with the problems associated with sampling benthic communities.

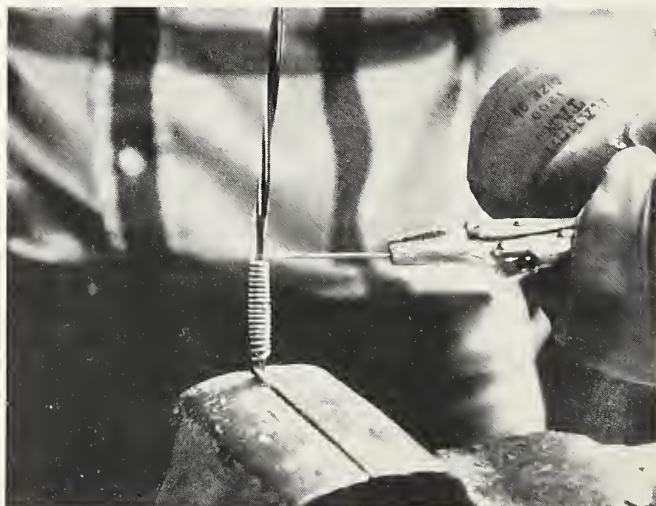


Figure 3. Wrapping the lower section of a brail hook with soft wire.



Figure 4. Five brail hooks (finished except for the beads) on a single chain.

FIELD GUIDE TO ENDANGERED MOLLUSKS

WES is gathering information to prepare a Field Guide to the endangered mollusks. This handbook will be in loose-leaf format and suitable for field, laboratory or office use. The textual material will be concisely written and include a glossary of technical terms and a literature cited section for those who wish to pursue selected topics in depth. For each major species treated, the guide will contain the following information:

- a. Scientific name, common name(s)
- b. Status (endangered, etc.)
- c. Identifying features
- d. Confusing species (if present)
- e. Habitat
- f. Range in the United States
- g. Remarks

In addition, each species will be accompanied by color plates which will illustrate anatomical features of both interior and exterior views of each shell. A written description of these identifying features will accompany the color plates. If necessary a paragraph on possible confusing species will be included. This will be written so that the user can decide whether or not he now holds, or has the potential of collecting, the species in question. Separating factors could include one or all of the following: range in the United States, habitat requirements, or specific features of shell morphology. If deemed appropriate, a color plate of the confusing species will be included. The textual material on habitat requirements will be as specific as possible. In many cases precise information on the ecological requirements for each species is not obtainable. However, when available, this section will include data on water depths, sediment types, water quality tolerances, etc., for the species under consideration. Information on range will be specific without providing a vehicle for exploitation of the resource. Depending on the species, range information will delineate watersheds, names of major rivers, or ranges of river miles where the organism has been collected.

LITERATURE RETRIEVAL SYSTEM

Technical literature pertaining to the objectives of the Endangered Mollusk Study will be made available to District personnel and other interested parties by way of an automated literature search and retrieval system. We are presently storing on the WES computer a ten-line abstract, selected key words, and the complete citation for all publications which relate to the objectives of this work unit. A program, written in FORTRAN IV, accesses these data files. An individual can obtain bibliographic information describing the habitat requirements, distribution and available sampling techniques for common, uncommon, and endangered freshwater mollusks. The literature was collected by Dr. Arthur H. Clarke & ECOSEARCH Inc. and WES personnel during this study. Material was obtained from the scientific literature, unpublished reports and impact studies conducted by Federal agencies. The bibliographic material is stored on the computer in a sequential data file. Each bibliographic entry requires 16 lines; the first line contains the date of publication and the author's (or authors') name(s). The second and third line are for the title, the fourth line for the source of publication and the fifth and sixth lines are reserved for keywords. Ten lines are available for a short summary or abstract of each publication. The literature on file can be searched for by keyword, author's name, date of publication or by any word which could appear in the title of abstract. The program first scans all bibliographic data and counts the number of entries present which satisfy the search criteria. After the publications are listed at the terminal, additional searches can be made as needed.

HABITAT CREATION

WES will design a gravel bar to provide habitat for mollusks and fish at a site near Columbus, Mississippi on the Tombigbee River. When an appropriate design is prepared, the U.S. Army Engineer District, Mobile, will construct the habitat. This project has two objectives: partial mitigation of losses of running water habitat on the Tombigbee River caused by the Tennessee Tombigbee Waterway (TTW), and better understanding of problems associated with design and construction of artificially placed natural substrate material for aquatic organisms. Information obtained from the second objective should have application to other water resource projects in the United States.

This work will take place in the old river channel of the Tombigbee River, directly below the Columbus Lock and Dam at river mile 232.9, Columbus, Mississippi (Figures 5 and 6). The Columbus damsite is located in northeast Mississippi on the Tombigbee River approximately 149 miles above the confluence of the Warrior River. The river above Columbus has a drainage area of 4,470 square miles, is about 85 miles in length, and has an average width of 50 ft. This river is within the Coastal Plain with elevations ranging from 1000 ft mean sea level (msl) to 126 ft msl at the dam. The Columbus Lock and Dam structure at Columbus, Mississippi, is one of the five lock and dams developed as part of the TTW. This dam was completed in January 1981 and the lock and dam will be operational for navigation traffic by the summer of 1981. This project extends from Demopolis, Alabama, on the Tombigbee River to mile 215 on the Tennessee River near the common boundary of Tennessee, Mississippi, and Alabama. Development of the TTW includes removal of about 260 million yd³ of soil and construction of five lock and dam structures on the river. One hundred and ninety

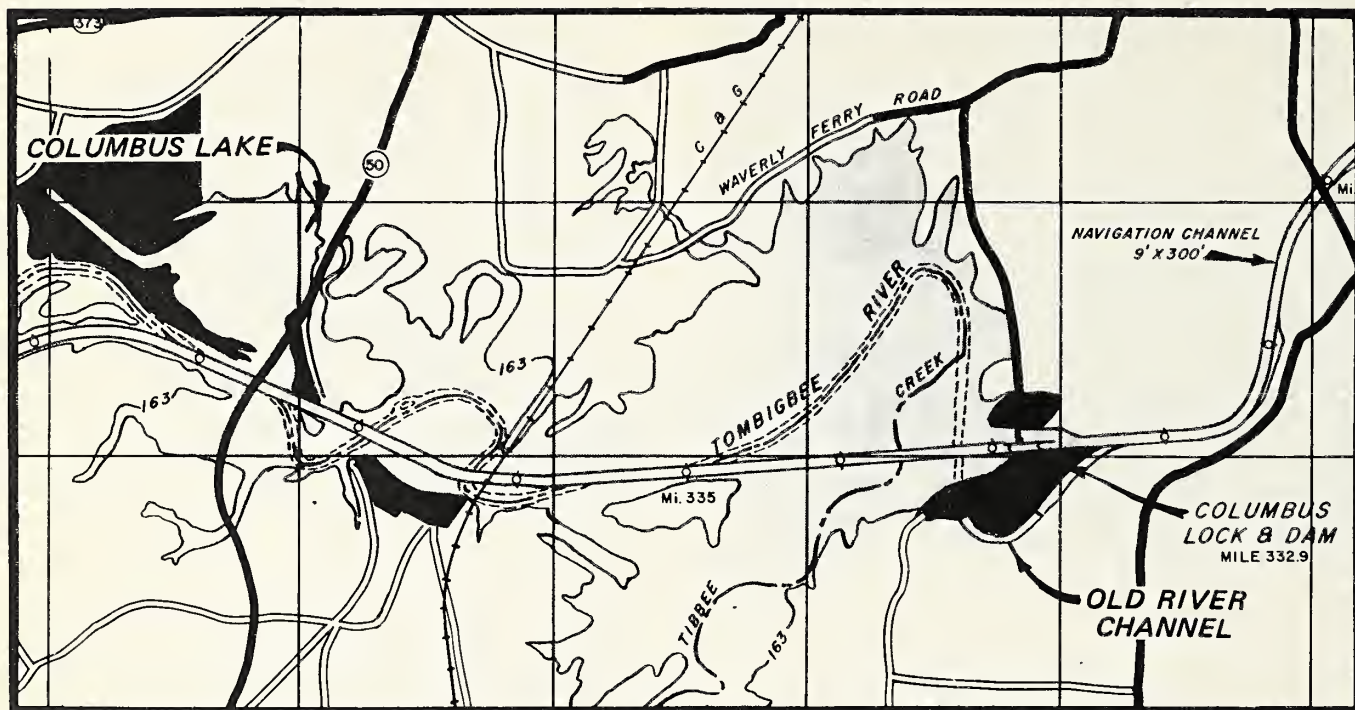


Figure 5. Vicinity Map, Columbus Lake, Mississippi

miles of free-flowing stream will be modified to form a series of run-of-the-river reservoirs and approximately 20 miles of oxbow lakes will be formed by bendway cutoffs. When completed, the project will provide a shortened route between the eastern gulf coast and the central United States (U.S. Army Engineer District, Mobile, 1970).

The study has been divided into three separate phases. These include (I) initial field evaluation of the project area, (II) design of the habitat, and (III) subsequent monitoring and possible seeding of the bar with mollusks. The actual construction of the bar will be the responsibility of the Mobile District. It is the intent of this study not only to design the habitat but also to judge its success and potential application to other areas of the country. The three phases of the project are described below:

Phase I

A background study of the biota and selected water quality parameters in the area of Columbus will be undertaken. Approximately 10 miles of river below the lock and dam will be evaluated using aerial photographs and maps. During a period of low water in the summer of 1981, the river will be surveyed for naturally occurring gravel bars or riffles. The locations of these bars and their approximate sizes will be recorded.

To the extent possible, two naturally occurring gravel bars in the river, judged to be similar in size and character to that planned for development, will be chosen for further studies. The following will be conducted at each area during low-flow conditions:

- a. Each naturally occurring gravel bar will be subdivided into equally sized subunits using a grid system. All physical features (configuration, water depths, exposed rocks or logs, emergent vegetation, etc.) will be recorded on a gridded map. A minimum of twelve sediment samples will be collected from the existing bar or riffle using a Ponar grab sampler. Sample sites



VICINITY MAP

Figure 6. Proposed site of the gravel bar habitat, old river channel, Tombigbee River, Mississippi

will be randomly chosen within various substrate types (if they exist) and the location of each recorded on the map. At each of the sites where sediment was collected, benthic samples (including unionids) will be taken using an appropriate sampler. In addition, a water sample (or samples) will be collected from each site: major cations, anions, dissolved gases and turbidity will be determined.

Phase II

Upon completion of the Phase I studies, a plan for a man-made gravel bar in the old river channel at mile 232.9 will be developed and furnished to the Mobile District for review and execution. The plan will, to the extent feasible, reproduce the natural requirements isolated in the Phase I studies. Preliminary indications are that some channel restrictions may be required to increase the flow in the river channel. These will have to have enough current above the substrate of the bar to adequately flush sediments deposited during high water. However, the habitat must be designed so that it is not eroded during high water. A simple method for increasing flow would be to construct a small levee or levees part way across the river at a specified site or sites. Possibly, more than one bar can be placed in the channel depending upon conditions of flow.

Phase III

Initiation of this portion of the work is dependent upon successful construction of the habitat. Once in place, the gravel bar will be monitored twice a year (once in the spring and once in the late summer) during periods of low flow. The purpose of these studies will be to assess the integrity of the gravel bar and to document colonization by aquatic organisms. To the extent feasible, all of the physicochemical measurements taken during Phase I will also be obtained during this phase of work.

Approximately two years after placement, WES will seed the gravel bar with one or more species of mature unionid mollusks. Seeding will be done only if the newly placed habitat is stable, is relatively free of suspended material and has been colonized successfully by invertebrate fauna. Species suited for transplanting should be common Tombigbee River forms; *Fusconaia ebena* or a species of *Quadrula* are likely choices. However, the final decision as to which species to seed will be based upon existing conditions on the bar and the river. The unionids will be collected from a site close to Columbus, identified, tagged and placed at specific sites in the substrate by hand. The procedures for collecting, marking and relocating the mollusks will be based upon methods used in a relocation study conducted in the Upper Mississippi River (Obland 1979). After this initial work, the success of these mollusks will be checked at least twice a year as part of the Phase III program. If transplanting these unionids is successful, consideration will be given to seeding the bar with some of the more uncommon unionids, particularly the species now under consideration for Federal protection by the U.S. Department of the Interior.

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NEARCTIC FRESHWATER SPHAERIACEA (BIVALVIA)

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ABSTRACT

Of thirty-eight sphaeriacean species in Nearctic North America, only *Pisidium ultramontanum*, a relict species found living only in northeastern California and south-central Oregon, is considered an endangered species. Two other species, *Sphaerium patella* and *Pisidium cruciatum*, are considered rare species, being found only in a few small populations in four adjacent west coast states and the Great Lakes drainage system, respectively. The endangered and rare species status are based on a frequency distribution of the number of species in 62 states, provinces and territories in Nearctic North America.

INTRODUCTION

There are five genera and thirty-eight species of sphaeriacean clams in Nearctic North America. They are strictly freshwater in occurrence and can be found in almost any type of aquatic habitat, from the deep, cold oligotrophic lakes of the arctic to the shallow roadside ditches in temperate and subtropical climates.

As in most taxa, there are species of Sphaeriacea that are extremely common with a cosmopolitan distribution and others that are very rare, occurring in a few isolated habitats. This report is the first to assess the rare and endangered status of

species of spaeriacean clams in Nearctic North America. They were not discussed at the first Symposium of Rare and Endangered Mollusks of North America (Clarke, 1970). None of the freshwater Spheariacea have so far been considered endangered.

For the purposes of this paper an endangered species is defined as one which is endemic to North America and is known living today from only one or a very few populations having a restricted range. A rare species is defined as one which is endemic or introduced and is restricted to a few places where they continue to maintain reproducing populations. Accordingly, an introduced species is not considered endangered in the country to which it has been introduced, in this case Nearctic North America.

THE NATURE OF FAUNA

For an objective measure of the rareness and commonness of the 38 species, their occurrence in each of the 50 states of the



Fig. 1. Distribution of *Pisidium ultramontanum* (shaded area = black dot) deemed to be an endangered species, and of *Sphaerium patella* (stippled area) and *Pisidium cruciatum* (cross-hatched area), both considered rare species.

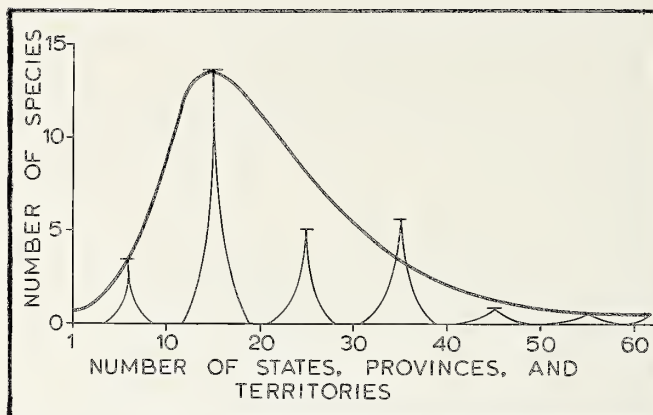


Fig. 2. A positively skewed frequency distribution of spheariacean species in 62 states, provinces and territories of Nearctic North America.

United States and in the 10 provinces and 2 territories of Canada were determined. The number of states, provinces and territories in which each species occurs is given in Table 1. The data are based on information in Britton and Morton (1977), Burch (1975), Clarke (1973), Heard (1965), Herrington (1962), Mackie and Huggins (1976, 1981), and Taylor (1960), and on the author's own extensive records and reference collections.

At least seven species are introduced (Table 1). Of these seven, one, *Corbicula fluminea*, has rapidly established itself as a nuisance organism. All introduced species are relatively uncommon, although *C. fluminea* and *Eupera cubensis* seem to be extending their range fairly rapidly.

RARE AND ENDANGERED SPECIES

The rarest species is *Pisidium ultramontanum* (Table 1). It is a relict species found only in northeastern California in the Upper Pit River drainage and in Eagle Lake, and in south-central Oregon in the Klamath drainage system (Fig. 1) (Taylor, 1960). The next least common species is *Pisidium punctiferum*, but it is an introduced species found living only in Florida and Texas. The most common species is *Pisidium casertanum* (Table 1).

When the number of species in 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, & 61-62 states, provinces and territories are plotted as a frequency distribution, a curve skewed to the left results (Fig. 2). The most rare species occur in the left tail and the most common species in the right tail of the frequency distribution. Most (fourteen) species are found in 11 to 19 of the 62 states, provinces and territories (Fig. 2).

Of greater interest in this type of frequency distribution are those species in the left tail. At the extreme left is *P. ultramontanum*. Only a very minor disturbance is needed to eliminate the species because it is restricted to only a small area. Specifically, any disturbance of the Klamath drainage and Upper Pit drainage systems will eradicate the species. I am unaware of any perturbations which are currently threatening the species in these drainage systems.

As one moves to the right in the frequency distribution, greater disturbances are needed to eradicate a species. For instance, *Sphaerium patella* is a rare species found living in small populations only in four adjacent states (Washington,

Table 1. Number of states, provinces and territories (out of 62) in which species of sphaeriacean clams have been found in Nearctic North America. The species are listed in order of increasing commonness. Introduced species are indicated by an asterisk.

Species	No.	Species	No.		
<i>Pisidium ultramontanum</i>	Prime, 1865	2	<i>Pisidium punctatum</i>	Sterki, 1895	15
<i>Pisidium punctiferum</i>	(Guppy, 1867)*	2	<i>Pisidium lilljeborgi</i>	Esmark & Hoyer, 1886	17
<i>Sphaerium corneum</i>	(Linnaeus, 1758)*	3	<i>Pisidium walkeri</i>	Sterki, 1895	17
<i>Sphaerium patella</i>	(Gould, 1850)	4	<i>Sphaerium rhomboideum</i>	(Say, 1822)	18
<i>Pisidium henslowanum</i>	(Sheppard, 1825)*	4	<i>Pisidium subtruncatum</i>	Malm, 1855	19
<i>Pisidium supinum</i>	Schmidt, 1850*	4	<i>Sphaerium simile</i>	(Say, 1816)	21
<i>Pisidium cruciatum</i>	Sterki, 1895	5	<i>Pisidium ventricosum</i>	Prime, 1851	22
<i>Pisidium amnicum</i>	(Müller, 1774)*	6	<i>Pisidium ferrugineum</i>	Prime, 1852	23
<i>Eupera cubensis</i>	(Prime, 1865)*	8	<i>Pisidium adamsi</i>	Stimpson, 1851	24
<i>Pisidium conventus</i>	Clessin, 1877	9	<i>Sphaerium occidentale</i>	(“Prime” Lewis, 1856)	28
<i>Corbicula fluminea</i>	(Müller, 1774)*	10	<i>Pisidium variabile</i>	Prime, 1852	31
<i>Pisidium aequilaterale</i>	Prime, 1852	12	<i>Musculium securis</i>	(Prime, 1852)	35
<i>Sphaerium fabale</i>	(Prime, 1852)	13	<i>Musculium transversum</i>	(Say, 1829)	35
<i>Pisidium idahoense</i>	Roper, 1890	13	<i>Pisidium nitidum</i>	Jenyns, 1832	37
<i>Pisidium milium</i>	Held, 1836	13	<i>Musculium partumeium</i>	(Say, 1822)	38
<i>Pisidium fallax</i>	Sterki, 1896	14	<i>Musculium lacustre</i>	(Müller, 1774)	39
<i>Sphaerium nitidum</i>	Westerlund, 1876	14	<i>Pisidium compressum</i>	Prime, 1852	40
<i>Pisidium dubium</i>	(Say, 1816)	15	<i>Sphaerium striatinum</i>	(Lamarck, 1818)	52
<i>Pisidium insigne</i>	Gabb, 1868	15	<i>Pisidium casertanum</i>	(Poli, 1791)	61

Oregon, Idaho, California) on the west coast (Fig. 1). Several watersheds would have to be upset before the species would be eradicated. There are insufficient data to determine if *S. patella* is a threatened or endangered species. Similarly, *Pisidium cruciatum* is a rare species being found only as small populations in the Great Lakes drainage system (Fig. 1), and a major upset in several rivers would be required to eradicate the species.

Clearly, species in the right tail of Fig. 2 are so common that they are not likely to ever be endangered, without destroying the continent first. The species most prone to eradication are those in the left tail of the frequency distribution. These species need to be very carefully studied in terms of life histories, ecology, and distribution before a habitat is altered or destroyed. This is especially true for species at the extreme left, namely *P. ultramontanum*.

It is interesting to note that the frequency distribution of Sphaeriacea in Fig. 2 is positively skewed. This implies that a lot of species are susceptible to eradication if a drainage system that affects fifteen states, provinces or territories is destroyed. Al-

though this is unlikely, a "healthier" distribution would seem to be a normal distribution (Fig. 3) since an environmental impact would affect fewer species in the left tail than the positively skewed distribution (Fig. 2). Negative skewness implies that most species are very common, a feature that is probably rare in most taxa.

The positive skewness of sphaeriacean distribution may be an artifact. By plotting the number of species against the number of states, provinces, and territories, equal weight is given to all areas. That is, all species are assumed to occur with similar probabilities in all areas. In fact, some states and provinces (e.g. New York, Michigan, Ontario) have very prolific and diverse sphaeriacean faunas, while others (e.g. Alaska, Hawaii) are somewhat depauperate. Perhaps the frequency distribution of Sphaeriacea would be normal if the numbers of species were plotted instead against the number of counties, but such information is not readily or easily available.

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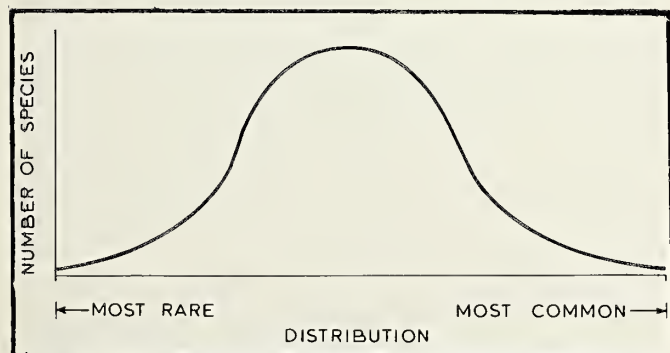


Fig. 3. A normal frequency distribution of species in a taxon.

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SOME RARE AND RESTRICTED PLEUROCERID RIVER SNAILS OF THE OHIO-MISSISSIPPI RIVER BASIN

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ABSTRACT

Several Pleuroceridae, including the AMU's symbolic *Io fluviialis*, have been proposed for inclusion on the federal list of endangered and threatened animals. These taxa and other pleurocerid forms are discussed, their known ranges summarized, and new records are presented.

RARE AND ENDANGERED SPECIES: FRESHWATER GASTROPODS OF SOUTHERN NEW ENGLAND

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ABSTRACT

Species once recorded for southern New England but no longer in evidence include: *Cincinnatia cincinnatiensis*, *Amnicola walkeri*, *Marstonia decepta*, and *Pomatiopsis lapidaria*. *Goniobasis virginica* has become narrowly restricted. Additional rare species include two prosobranchs and six pulmonates. Acid rain poses a threat to naturally acidic, low calcium, poorly buffered habitats.

This report on the rare and endangered species of freshwater gastropods of southern New England is based on data collected over the past four years (Jokinen, in review). Field sampling was concentrated in Connecticut but included parts of southern Massachusetts east to Cape Cod (69 55 W to 73 45' W, 40 00' N to 42 03' N). Water chemistry data were collected along with the snails. Collection methods and water analysis techniques have been described elsewhere (Jokinen, 1978). Voucher specimens have been placed in the Museum of Comparative Zoology, Harvard University, the Florida State Museum, and the Museum of Zoology, The University of Michigan.

MISSING SPECIES: Southern New England has historically undergone numerous changes, especially in the impoundment of its waterways to run the mills, for flood control, and for reservoirs and recreation. Lentic habitats are consequently far more numerous than 200 years ago. This, as well as industrial utilization of the streams, has decreased the abundance of river species while increasing the number of available habitats for lake and pond species.

Rev. Linsley's (1845) catalogue of the freshwater snails of western Connecticut allows us to trace molluscan changes over the past century. Linsley listed several species of prosobranchs which then occurred in the Housatonic River. These species were (using modern nomenclature): *Cincinnatia cincinnatiensis* (Anthony), *Amnicola walkeri* Pilsbry, *Marstonia decepta* (Baker), and *Pomatiopsis lapidaria* (Say). These species presently occur in New York (Dundee, 1957; Harman & Berg, 1971) but are no longer apparent in Connecticut. *P. lapidaria* is amphibious to terrestrial in habit and may have been overlooked. The other species are reported from large rivers and lakes and it is probable that the pollution of the Housatonic over the past century destroyed most of the molluscs. The river as a whole is poor in gastropods.

RARE SPECIES: Snails which are present but rare in Connecticut are: prosobranchs: *Goniobasis virginica* (see Smith, 1980), *Valvata sincera*, and *Viviparus georgianus*; Pulmonata: *Fossaria parva*, *F. exigua*, *F. rustica*, *Stagnicola catascopium*, *Aplexa elongata*, *Gyraulus circumstriatus*, and *Ferrissia walkeri*. Of these species, *G. virginica* and *S. catascopium* are on the edges of their ranges and may be limited to hard water. *F. exigua* and *F. rustica* may be variations of *F. modicella*. The taxonomy of these fossarine lymnaeids is too confused to draw either geographical or ecological conclusions. *A. elongata* tends to prefer hard-water temporary ponds and these are nonexistent in the eastern and western crystalline highlands of the state. Hardwater temporary ponds were undersampled in this survey and it is likely that *A. elongata* is more abundant in the marble valleys. It is not uncommon in New York. Little is known about the biology of *G. circumstriatus* because of past confusion with *G. parvus*. *V. georgianus* exists in one hard-water and one soft-water lake in Connecticut and has also been found in one lake in Massachusetts. This species is probably on the edge of its range. *V. sincera* does not seem to be an abundant snail in any part of its range. Little is known about the biology of this species.

GEOLOGY: Southern New England is part of the glaciated northern Atlantic drainage system. The area has a wide range of bedrock types which yield diverse aquatic habitats. The central valley of Connecticut, containing much of the Connecticut River, is composed of Triassic sandstone interbedded with marlstone. The marl causes the water to be moderately hard with calcium values ranging from 8 to 24 ppm Ca+++. The eastern and western highlands lie on either side of the central valley. The highlands are composed of gneiss and schist and yield very soft waters with calcium values as low as 1-2 ppm and pH's down to 5.4. The western end of the state contains the marble valleys with waters high in calcium (Ca++ 20 ppm).

The above geological regions show differences in snail community structure. Species such as *Stagnicola elodes* and *Helisoma triivolis* are common in the ponds of the calcium-rich central valley but are scarce in the soft water habitats of the highlands. *Valvata tricarinata* is limited to the hardwater lakes of the marble valley and parts of the lower central valley. *Gyraulus circumstriatus* and *Ferrissia fragilis* are most common in the softer waters, as is *Physa skinneri*. Other species, such as *Helisoma anceps*, *Amnicola limosa*, and *Physa heterostropha* are ubiquitous. Table 1 lists the 35 species of freshwater snails found in southern New England and summarizes the water chemistry preferences and relative abundances.

Much of southern New England has naturally soft, unbuffered, low calcium, low pH fresh water. These soft-water streams, impoundments, lakes and ponds harbor a surprising number of snail species. These habitats, however, are unbuffer-

SPECIES	ABUNDANCE	CALCIUM HARDNESS PREFERENCES			
PROSOBRANCHIA			<i>Pseudosuccinea columella</i> (Say, 1817)	3	Soft to medium
Viviparidae			Physidae		
<i>Viviparus geogianus</i> (Lea, 1834)	1	Ubiquitous	<i>Aplexa elongata</i> (Say, 1821)	1	N.D. (hard?)
<i>Cipangopaludina chinensis</i> (Gray, 1834)	2	Medium to hard	<i>Physa skinneri</i> Taylor, 1953	2	Soft to medium
<i>Campeloma decisum</i> (Say, 1817)	3	Ubiquitous	<i>Physella ancillaria</i> (Say, 1825)	2	Ubiquitous
Valvatidae			<i>Physella heterostropha</i> (Say, 1817)	3	Ubiquitous
<i>Valvata tricarinata</i> (Say, 1817)	2	Hard water	<i>Physella gyrina</i> (Say, 1821)	2	Soft to medium
<i>Valvata sincera</i> Say, 1824	1	Hard water	Planorbidae		
Paludomidae (Pleuroceridae)			<i>Gyraulus parvus</i> (Say, 1817)	3	Ubiquitous
<i>Goniobasis virginica</i> (Gmelin, 1791)	1	Hard water	<i>Gyraulus circumstriatus</i> (Tryon, 1866)	1	Soft to medium
Hydrobiidae			<i>Gyraulus deflectus</i> (Say, 1824)	2	Ubiquitous
<i>Amnicola limosa</i> (Say, 1817)	3	Ubiquitous	<i>Helisoma anceps</i> (Menke, 1830)	3	Ubiquitous
<i>Lyogyrus pupoidea</i> (Gould, 1840)	2	Ubiquitous	<i>Helisoma trivolvis</i> (Say, 1817)	2	Medium to hard
<i>Lyogyrus granum</i> (Say, 1822)	2	Medium to hard	<i>Helisoma campanulatum</i> (Say, 1821)	2	Ubiquitous
PULMONATA			<i>Menetus dilatatus</i> (Gould, 1841)	3	Ubiquitous
Lymnaeidae			<i>Promenetus exacuus</i> (Say, 1821)	2	Ubiquitous
<i>Fossaria parva</i> (Lea, 1841)	1	Soft	<i>Planorbula armigera</i> (Say, 1818)	2	Soft to medium
<i>Fossaria modicella</i> (Say, 1825)	2	Ubiquitous	Ancylidae		
<i>Fossaria exigua</i> (Lea, 1841)	1	N.D.	<i>Laevapex fuscus</i> (C.B. Adams, 1840)	2	Ubiquitous
<i>Fossaria rustica</i> (Lea, 1851)	1	N.D.	<i>Ferrissia rivularis</i> (Say, 1819)	2	Ubiquitous
<i>Stagnicola elodes</i> (Say, 1821)	2	Medium to hard	<i>Ferrissia parallela</i> (Haldeman, 1841)	2	Ubiquitous
<i>Stagnicola catascopium</i> (Say, 1817)	1	Hard	<i>Ferrissia fragilis</i> (Tryon, 1863)	3	Soft to medium
			<i>Ferrissia walkeri</i> (Pilsbry & Harris, 1906)	1	Soft

Table 1. Freshwater gastropods of southern New England. Relative abundances designated in column 2: 3 = common, found in at least 20% of the sample sites; 2 = moderately common, in at least 4% of the sites; 1 =

rare, found in less than 4% of the sites; N.D. = no data. Calcium hardness values: soft water = 5ppm Ca ++; medium = 5-20 ppm; hard = 20ppm.

ed against decreases in pH caused by an influx of acid rain and are poorly protected against heavy metal toxicity. Some lakes on Cape Cod have already been removed from trout stocking because of high acidity levels. Not only are the fish in danger but the molluscs as well. The current survey of freshwater gastropods, which includes a measure of the chemical parameters, should serve as a baseline to allow us to monitor future changes in the molluscan fauna.

ACKNOWLEDGMENTS

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THE ENDANGERED LAND SNAILS OF THE EASTERN UNITED STATES

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ABSTRACT

The following species are considered potentially endangered because of limited ranges or are found in areas undergoing rapid development with destruction of their habitats, such as the Florida Keys: *Cepolis varians*, *Stenotrema pilsbryi*, *Stenotrema hubrichti*, *Mesodon clausus*, *Mesodon archeri*, *Mesodon clenchi*, *Triodopsis platysayoides*, *Triodopsis occidentalis*, *Cerion incanum*, *Glyphyalinia pecki*, *Paravitrea aulacogyra*, *anguispira picta*, *Discus macclintocki*, *Polygyriscus virginianus*, *Helicodiscus hexodon*, *Helicodiscus diadema*, *Helicodiscus lirellus*, *Vertigo alabamensis*, *Vertigo hebari*, *Bothriopupa variolosa*, *Sterkia eyriesi rhoadsi*, *Lucidella tantilla*.

Since publishing my first list of the endangered land snails of the eastern United States in 1972 (Sterkiana 45: 33), additional collecting has revealed that some of the species were not as restricted in their ranges as was believed. Other species have been found to be invalid. At the present time I would consider the following species to be potentially endangered because of limited ranges or are found in areas undergoing rapid development with destruction of their habitats, such as the Florida Keys. *Cepolis varians* (Menke). Known only from the Florida Keys. *Stenotrema pilsbryi* (Ferriss). Known only from the north side of Rich Mountain on the Arkansas-Oklahoma border.

- Stenotrema hubrichti* Pilsbry. Known only from the Mississippi River bluff at Pine Hills, Union Co., Illinois.
- Mesodon clausus trossulus* Hubricht. Known only from near the type locality in Clarke Co., Alabama.
- Mesodon archeri* Pilsbry. Known only from near the mouth of Goforth Creek, Polk Co., Tennessee.
- Mesodon clenchi* (Rehder). Known only from a rock slide on Mt. Nebo, Yell Co., Arkansas.
- Triodopsis platysayoides* (Brooks). Known only from below Coopers Rock, Monongalia Co., West Virginia.
- Triodopsis occidentalis* (Pilsbry & Ferriss). Known only from wooded hillsides west of Locust Grove, Independence Co., Arkansas.
- Cerion incanum* (Binney). Known only from the Florida Keys, where it is rapidly disappearing due to overcollecting for shell jewelry.
- Glyphyalinia pecki* Hubricht. Known only from caves near Clay, Jefferson Co., Alabama.
- Paravitrea aulacogyra* (Pilsbry & Ferriss). This species is known only from a single dead shell found on the north side of Magazine Mountain, Logan Co., Arkansas. Although it looks very much like a *Paravitrea*, it may be the young of some other species, as the shell is larger and has fewer whorls than other species of *Paravitrea*.
- Anguispira picta* (Clapp). Known only from Buck Creek Cove, Franklin Co., Tennessee.
- Discus macclintocki* (F.C. Baker). Known only from about the mouth of a cave in Bixby Park, Clayton Co., Iowa.
- Polygyriscus virginianus* (Burch). Known only from the New River bluff, opposite Radford, in Montgomery Co., Virginia.
- Helicodiscus hexodon* Hubricht. Known only from the base of Walden Ridge, southeast of Pikesville, Bledsoe Co., Tennessee.
- Helicodiscus diadema* Grimm. Known only from a hillside, 10 miles NNE. of Covington, Alleghany Co., Virginia.
- Helicodiscus lirellus* Hubricht. Known only from the base of a hill, 10 miles northwest of Lexington, Rockbridge Co., Virginia.
- Vertigo alabamensis* (Clapp). The type locality was probably destroyed by the construction of a dam on the Black Warrior River, Tuscaloosa Co., Alabama.
- Vertigo hebardi* Vanatta. Known only from the Florida Keys. I have never been able to find it.
- Bothriopupa variolosa* (Gould). Known only from southern Florida. I have not been able to find it.
- Starkia ayriesi rhoadsi* (Pilsbry). Known only from southern Florida. I found a single specimen in Matheson Hammock Park, Dade Co., Florida.
- Lucidella tantilla* (Pilsbry). Known only from southern Florida. I found it abundant in a small hammock remnant on Key Largo. It does not seem able to survive fires.

THE ECOLOGY AND DISTRIBUTION OF *MONADENIA SETOSA*

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ABSTRACT

Current field work indicates broader habitat preference and wider (but still restricted) geographic range for *Monadenia*

setosa than previously reported. Genital similarity and an apparent zone of intermediates suggest that *M. setosa* is a subspecies of *M. fidelis*. Similar phenetic relationships exist elsewhere in northern California.

ENDANGERED SPECIES — WHY WORRY?

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Imagine continuing at our present rate of massacre: we are striving to kill off all plants and animals except our domestic ones. Most of us kill everything in our paths — snakes, mosquitoes, pigeons, wolves and so on and on. We hunt and fish needlessly; we use furs; we kill everything that stands in the way of commercial fishing; we keep pressure on species rentlessly taking "crops" of shrimp, oysters, clams, crayfishes, lobsters, fishes, and others with never a season off so they can repopulate; we keep destroying habitats by dredging, filling, and draining bodies of water; we keep polluting land, water and air so that other organisms can't survive; we revise the climax vegetation by removing forests, deserts, grasslands and replacing them with what we desire; and we occupy many habitats with our cities, roads, and other man-made structures. Animals and plants that are not killed outright by us have no place to live and/or to reproduce.

How well have we succeeded? Have we managed to actually kill off any species? Unfortunately the answer is "yes, we are very successful". The list is long; here are a few of the better known examples:

- Mammals: Meadow Vole, *Microtus californicus scirpensis*; California
Plains wolf, *Canis lupus nubilus*. Great Plains
Sea mink, *Mustela macrodon*. New England coast
Steller's Sea cow, *Hydrodamalis stelleri*.
North Pacific
Eastern elk, *Cervus canadensis canadensis*.
U.S. east of Plains
Badlands bighorn sheep, *Ovis canadensis auduboni*. N and S Dakota
Caribbean Monk seal, *Monachus tropicalis*.
Caribbean and Gulf
- Birds: Labrador duck, *Camptorhynchus labradorium*. NE
N. America
Heath hen, *Tympanuchus cupido cupido*. E. U.S.
Great auk, *Pinguinus impennis*. N. Atlantic ocean
Passenger pigeon, *Ectopistes migratorius*. N.
America
Louisiana parakeet, *Conuropsis carolinensis ludoviciana*. S. U.S.
- Fishes: San Geronio trout, *Salmo evermanni*. Santa Ana
River, CA
Big Spring spinedace, *Lepidomeda mollispinis pratensis*. Spring-fed marsh, Lincoln, Co.,
Nevada
Harelip sucker, *Lagochila lacera*. Clear streams of
upper Miss. valley; Tennessee River in
Georgia;
White River in Arkansas, Lake Erie drainage,
etc.
- Freshwater
mussels: *Dysnomia flexuosa*. Ohio River
Dysnomia sampsoni. Wabash River

Freshwater

snails: *Goniobasis catenoides*. Chattahoochee River,
Columbus, GA

But you say, "aren't we doing O.K. now since we have various organizations alerting us and policing us?" All you must do to answer that is listen to or read the news. Daily there are reports about new housing developments, new resorts, new roads, buildings, dredgings, whale and dolphin massacres, poaching on African big game; elephants and walrus being slaughtered by the thousands for their tusks; rattlesnake round-ups. Just listen and answer the question for yourself. Despite all of the agencies and assorted individuals trying to hold together our precious fauna and flora, we are still desperately trying to eradicate all of it.

Let's assume that we succeed in eliminating all of these "unnecessary" organisms and keep our human population increasing just as it is. First, can you imagine nothing here except man, cows, chickens, pigs and crops? If you've had any training in biology, you know immediately that that situation could not exist.

Every organism in nature is dependent on others. If you will recall a basic food chain, you realize that plants are the base (primary producers); smaller animals (or sometimes even large ones) feed on the plants (primary consumers), larger animals feed on those (secondary consumers), and so on until one gets to the end of the chain. That end niche is usually occupied by the top carnivores. Or, to view it another way, it takes a large number of plants to support the primary consumers; it takes a large number of primary consumers to support fewer secondary consumers, and so on to the top of the ecological pyramid. So, you can see that, to eliminate pieces of the food chains or levels of the pyramid automatically eliminates those dependent upon those pieces.

Food is not the only problem in all of this. Every organism has some kind of role to play in the environment whether it be keeping the calcium cycle running (molluscs help do that job), cycling nitrogen, or even disposing of all the carcasses which result from daily plant and animal deaths. Man is absolutely dependent upon other organisms to do these and a multitude of similar jobs for him. Without those organisms man will not survive.

Why, then, do we persist in our wanton destruction of other organisms? Why don't we quit it? The only conclusion I can reach is that it is simply greed. The affluent societies, having material wealth as their base, demand more and more of everything. The non-affluents realize that the affluents want the material wealth (ivory, furs, plant products and so on) from their countries and they are now ruining their own faunas and floras to provide it and get a "fast buck". It all amounts to greed.

We must somehow, quickly, change the thinking of the world to the well-known ecological concept of "spaceship earth". We are all on this spaceship and have no way of getting off to live elsewhere. We have only so much of each resource and have no way of getting more when it is unavailable. We must learn to use our resources properly over and over and share them with all other organisms.

To get back to the thrust of this: why worry about endangered species? You may point out that species became extinct before man's arrival on this spaceship; that we have a well-documented history of extinctions: dinosaurs, ammonites, Ordovician cephalopods, belemnites, species of man — just to name a few. What, then, is all the fuss? Why are we having this symposium? Why not relax and quit worrying about endangered

species?

A few statistics will reveal the flaw in that type of behavior. Of the recorded extinctions of mammals over the past 2000 years, half (1000) have become extinct during the last 60 years! Obviously this points the finger right at man. Consider some of these figures:

in 1969 the US imported whole raw hides of 7,934 leopards, 1,885 cheetas, and 113,069 ocelots. That is for one year and one country!

in 1971 the US imported *living* organisms for various reasons: 103,500 live mammals, 995,000 live birds, 391,000 live amphibians, 98,971,000 live fishes, 1,404,200 live reptiles.

It is clear that wild species simply cannot continue to meet this enormous demand. This is a global problem.

So, in conclusion, there is obviously plenty to worry about. We, being malacologists, have automatically been assigned the task of worrying about the molluscs. Other specialist groups are concerned about various other biological groups. Obviously there are many invertebrates such as worms and the like about which possibly no one is worrying. Can you imagine the scoffing you would get if you said "we must protect all worms"?

In addition to our task of looking after the welfare of the molluscs, we must, in general, do as much as possible to educate our families, neighbors, friends to the necessity of *all* organisms having a chance to share this earth with us; they have as much right to it as we!

Please put endangered organisms and all others right at the top of your worry list.

PROTECTION OF MOLLUSKS UNDER THE ENDANGERED SPECIES ACT OF 1973

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ABSTRACT

A number of conservation measures are made available to a species and its habitat when it is listed as endangered or threatened under the Endangered Species Act of 1973, as amended. Now listed are 25 species or subspecies of freshwater bivalves and eight species or subspecies of terrestrial gastropods in addition to all species of the gastropod genus *Achatinella*.

INTRODUCTION

The purposes of this Act are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species, and to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth in subsection (a) of this section.

With this statement, which is section 2(b) of the Endangered Species Act of 1973, as amended, Congress succinctly summarized the intent of the Act. The means of achieving these purposes are then enumerated in following sections of the Act. The National Marine Fisheries Service, Department of Commerce, has been given the responsibility for carrying out the provisions of the Act for marine species, while the Fish and

Wildlife Service, Department of the Interior, has jurisdiction over nonmarine species. Amendments made to the Act from 1976 to 1979 have modified some features of the Act, especially with respect to procedures for adding species to the lists of endangered and threatened species. This paper summarizes some of the major features of the Act with respect to its application to freshwater and land mollusk conservation.

DEFINITIONS

Section 3 of the Act presents definitions of terms used in the Act. This section defines "endangered species" as "...any species which is in danger of extinction throughout all or a significant portion of its range. . ." A "threatened species" is defined as "...any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." For the purposes of the Act a "species" may be either a subspecies or species of invertebrate animal or plant. Before the 1978 amendments, distinct populations of these organisms could be listed as endangered or threatened. The 1978 amendments specified that individual populations could be listed only for vertebrates, excluding that consideration for mollusks and other invertebrates. "Critical Habitat" is defined to include areas "...on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection. . ." Critical habitat has not yet been designated for any species of mollusk. "Take" is defined as "...to harass, harm, pursue, hunt, shoot, wound, or collect, or to attempt to engage in any such conduct." The last definition was obviously written to cover threats to the many different kinds of eligible plants and animals that vary in size and habits: It is not meant to imply, for example, that Congress recognizes shooting and collecting as equals threats to mollusks or any other single group.

DETERMINATION OF ENDANGERED AND THREATENED SPECIES

Section 4 of the Act deals with the criteria and procedures for listing Species as threatened or endangered and determining their critical habitat. It is important to note that species can be listed under the Act only by regulation. As regulations, listings are subject to review by various Federal offices for their compliance with executive orders and other regulations.

The Act recognizes the following factors that may affect a species and thereby make it eligible for endangered or threatened status:

- (1) the present or threatened destruction, modification, or curtailment of its habitat or range;
- (2) overutilization for commercial, sporting, scientific, or educational purposes;
- (3) disease or predation;
- (4) the inadequacy of existing regulatory mechanisms; or
- (5) other natural or manmade factors affecting its continued existence

The mollusk species or subspecies that are now listed as threatened or endangered are identified in Table 1. *Papustyla pulcherrima*, the Manus Island tree snail, was the first mollusk listed under the Act. That species was actually listed in 1970 under a

previous act: the Endangered Species Conservation Act of 1969. The protections provided by the 1969 Act were limited to regulation of trade and making available funds for land acquisition. With the passage of the Endangered Species Act in 1973, *Papustyla pulcherrima* was automatically listed under this newer, broader law. In June 1976, 24 species and subspecies of unionid mussels were listed as endangered. *Epioblasma walkeri*, another unionid, was listed as endangered in August 1977. In July 1978, one subspecies and 4 species of land snails were listed as threatened and two species were listed as endangered. These were the last mollusks listed before the 1978 amendments to the Act.

The 1979 amendments significantly altered listing procedures. The most significant changes dealt with the designation of critical habitat, which had been optional with species listings prior to these amendments. In most cases, critical habitat must now be designated for each species when it is listed. Of greater significance is the requirement that the economic impact of designating an area as a critical habitat now be assessed. This requires the preparation of an economic impact analysis for each proposed critical habitat designation and therefore for most species listings. Other requirements specified by the 1978 amendments deal with time limits on the promulgation of final listings following proposed listings and requirements for public meetings on all critical habitat designations.

Regulations listing the entire genus *Achatinella* (Oahu tree snails) as endangered were published in January 1981. Nineteen of the 42 species recognized by Kondo (1970) are thought to survive in the mountains of Oahu. The effective date of these regulations was delayed by the President's Executive Order 12291 of February 17, 1981 which requires additional review of pending or new regulations in order to reduce regulatory burdens. These regulations became effective on August 31, 1981 following their examination for compliance with Executive Order 12291.

The 1978 amendments specify that an exception may be made to the required designation of critical habitat when listing a species if the benefits to the species of not designating its critical habitat outweigh the benefits of designating its critical habitat. Such an exception was made in the listing of *Achatinella* when the U.S. Fish and Wildlife Service determined that the publication of locality maps, which is required for critical habitat designation, would further expose these species to the major threat of over-collection.

The nature of critical habitat is frequently misunderstood. Critical habitat designation is meant to alert Federal agencies to the importance of a given locality to a listed species so that the protection of Section 7 of the Act (discussed below) can be implemented. Although Federal activities may be modified or restricted within an area that is designated as critical habitat, that area does not become a nature reserve or park or change its ownership.

Section 4 allows the writing of special regulations for threatened species at the time of listing. For example, if a threatened species is not threatened by taking, a special regulation may be written to allow taking under specified circumstances. Aside from this opportunity to promulgate more flexible rules for a threatened species, endangered and threatened species receive identical protection under the Act.

Table 1. Mollusks on the U.S. Lists of Endangered and Threatened Species as of October 1981.

<u>Common Name</u>	<u>Scientific Name</u>	<u>Historic Range</u>	<u>Status*</u>	<u>When** Listed</u>
Class Gastropoda				
Order Stylommatophora				
Family Achatinellidae:				
Oahu tree snails	<u>Achatinella</u> , all species	HA	E	5
Family Succineidae:				
Chittenango ovate amber snail	<u>Succinea chittenangoensis</u> (Pilsbry, 1908)	NY	T	4
Family Bulimulidae:				
Stock Island snail	<u>Orthalicus reses</u> (Say, 1830)	FL	T	4
Family Discidae:				
Iowa Pleistocene snail	<u>Discus macclintocki</u> (Baker, 1928)	IA	E	4
painted snake coiled forest snail	<u>Anguispira picta</u> (Clapp, 1920)	TN	T	4
Family Polygridae:				
flat-spined three-toothed snail	<u>Tridopsis platysayoides</u> (Brooks, 1933)	WV	T	4
noonday snail	<u>Mesodon clarki nantahala</u> (Clench & Banks, 1932)	NC	T	4
Family Helicodiscidae:				
Virginia fringed mountain snail	<u>Polygyriscus virginianus</u> (Burch, 1947)	VA	E	4
Family Camaenidae:				
Manus Island tree snail	<u>Papustyla pulcherimma</u> (Rensch, 1931)	Admiralty Islands (Manus Islands)	E	1
Class Bivalvia				
Family Unionidae:				
Alabama lamp pearly mussel	<u>Lampsilis virescens</u> (Lea, 1858)	AL, TN	E	2
Appalachian monkeyface pearly mussel	<u>Quadrula sparsa</u> (Lea, 1841)	TN, VA	E	2
birdwing pearly mussel	<u>Conradilla caelata</u> (Conrad, 1834)	TN, VA	E	2
Cumberland bean pearly mussel	<u>Villosa</u> (=Micromya) <u>trabalis</u> (Conrad, 1836)	KY	E	2
Cumberland monkeyface pearly mussel	<u>Quadrula intermedia</u> (Conrad, 1836)	AL, TN, VA	E	2
Curtis' pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>florentina curtisi</u> (Frierson & Utterbach, 1916)	MO	E	2
dromedary pearly mussel	<u>Dromus dromas</u> (Lea, 1834)	TN, VA	E	2
green-blossom pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>torulosa gubernaculum</u> (Reeve, 1865)	TN, VA	E	2
Higgin's eye pearly mussel	<u>Lampsilis higginsii</u> (Lea, 1857)	IL, IA, MN, MO, NE, WI	E	2

Table 1 (continued)

<u>Common Name</u>	<u>Scientific Name</u>	<u>Historic Range</u>	<u>Status*</u>	<u>When** Listed</u>
Micklin's pearly mussel	<u>Megaloniais nicklineana</u> (Lea, 1834)	Mexico	E	2
orange-footed pearly mussel	<u>Plethobasis cooperianus</u> (Lea, 1834)	AL,IN,IA, KY,OH,PA,TN	E	2
pale lilliput pearly mussel	<u>Toxolasma</u> (=Carunculina) <u>cylindrella</u> (Lea, 1868)	AL,MO,WV, TN	E	2
pick musket pearly mussel	<u>Lampsilis orbiculata</u> (Hildreth, 1828)	AL,IL,MO, OH,PA,KY,IN, WV,TN	E	2
Sampson's pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>sampsoni</u> (Lea, 1861)	IL,IN	E	2
Tampico pearly mussel	<u>Cyrtonanaias tampicoensis teconatensis</u> (Lea, 1841)	Mexico	E	2
tubercled-blossom pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>torulosa</u> (Rafinesque, 1820)	IL,KY,TN, WV	E	2
turgid-blossom pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>turgidula</u> (Lea, 1858)	AL,AR,MO, TN	E	2
white cat's paw pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>sulcata delicata</u> (Simpson, 1900)	IN,MI,OH	E	2
white wartyback pearly mussel	<u>Plethobasis cicatricosus</u> (Say, 1829)	AL,TN	E	2
yellow-blossom pearly mussel	<u>Epioblasma</u> (=Dysnomia) <u>florentina</u> <u>florentina</u> (Lea, 1857)	AL,TN	E	2
fine-rayed pigtoe	<u>Fusconaia cuneolus</u> (Lea, 1840)	AL,TN,VA	E	2
rough pigtoe	<u>Pleurobema plenum</u> (Lea, 1840)	KY,TN,VA	E	2
shiny pigtoe	<u>Fusconaia edgariana</u> (Lea, 1840)	AL,TN,VA	E	2
fat pocketbook	<u>Potamilus</u> (=Proptera) <u>capax</u> (Green, 1832)	AR,IN,MO, OH		
tan rifle shell	<u>Epioblasma</u> (=Dysnomia) <u>walkeri</u> (Wilson & Clark, 1914)	KY,TN,VA	E	3

*E-Endangered, T-Threatened

**1: 35 Federal Register 8495: June 2, 1970
2: 41 F. R. 24064; June 14, 1976
3: 42 F. R. 42353; August 23, 1977

4: 43 F. R. 28932; July 3, 1978
5: 46 F. R. 3178; January 13, 1981

Section 4 also allows for individuals to petition the appropriate agency to list species. The required contents of a petition are described in detail in Section 424.14 of Part 424 of Title 50 of the U.S. Code of Federal Regulations. Generally, a person submitting a petition should identify the species, its habitat, areas recommended for critical habitat designation, any adverse effects of critical habitat designation, and threats. Petitions should contain detailed information and provide all possible documentation. If the petition is accepted, the Service conducts and publishes a status review of the species and, based on the results of this review, may propose protective status.

Section 4 also allows for the formulation of recovery plans for listed species which may be directed by an appointed recovery team. Recovery teams have been appointed for *Lampsilis higginsii* and *Succinea chittenangoensis*. Draft recovery plans

are being prepared for *Triodopsis platysayoides* by the Annapolis Area Office of the Fish and Wildlife Service and for *Orthalicus reses* through the Service's Gainesville Field Station (Florida). Negotiations are now being carried out with various individuals and organizations to develop recovery plans for *Anguispira picta*, *Polygyris virginiensis*, and several listed unionids in the upper Tennessee River drainage.

LAND ACQUISITION

Section 5 of the Act makes the funds and land acquisition authority of previous conservation acts available to listed species. No lands have as yet been acquired to protect a listed mollusk. Mollusk species may, however, receive some habitat protection through the acquisition of their habitat for the benefit of another listed organism. For example, a portion of the Nevada spring

habitat of the endangered fish *Moapa coriacea* Hubbs & Miller, 1948 has been acquired by the Fish and Wildlife Service. These springs are also the habitat of *Fluminicola avernalis* Pilsbry, 1935 (Hydrobiidae), which had formerly been proposed as a threatened species and remains a candidate for listing.

All or a large portion of the known habitats of the listed land snails *S. chittengoensis*, *T. platysayoides*, and *D. macchintocki* are already within state parks and *M. clarki nantahala* is within Nantahala National Forest.

COOPERATION WITH THE STATES

Section 6 of the Act makes funds available to states for the conservation of endangered and threatened species. States must enter into a cooperative agreement with the Federal government to receive these funds and most states have done so. These funds may be used for the protection of federally listed species or to establish state endangered species programs as has been done in California. Since the passage of the Act, cooperative agreements with states have resulted in the expenditure of \$334,000 in federal funds for mollusk conservation, mostly for field studies. Some of these funds contributed to the production of *Endangered and Threatened Wildlife of Kentucky, North Carolina, South Carolina, and Tennessee* (Parker & Dixon, 1980), which contains photographs and species accounts for several listed mollusks. The future of cooperative grants to the states for endangered species is now uncertain since no funds have been budgeted for these purposes in the proposed fiscal year 1982 Fish and Wildlife Service budget.

CONSULTATION

Section 7 of the Act requires Federal agencies to insure, through consultation with the Fish and Wildlife Service or the National Marine Fisheries Service, that their actions are not likely to jeopardize the continued existence of an endangered or threatened species. The usual result of such consultation is the finding that the Federal activity does not jeopardize the species or the activity can be modified so as to avoid jeopardy. Most consultations concerning mollusks have dealt with permit applications for survey work or the taking of scientific specimens. A Federal activity that would be likely to jeopardize the continued existence of a species may be exempted only by a special Endangered Species Committee or by a special act of Congress. The exemption process through the Endangered Species Committee was added by the 1978 amendments to the Act. It should be noted that the protections of Section 7 apply only to activities authorized, funded, or carried out by Federal agencies and do not apply to public or private activities that do not have Federal involvement.

PROHIBITED ACTS AND EXCEPTIONS

Section 9(a) (1) specifies the following activities are prohibited with respect to listed species:

- (A) import any such species into, or export any such species from the United States;
- (B) take any such species within the United States or the territorial sea of the United States;
- (C) take any such species upon the high seas;
- (D) possess, sell, deliver, carry, transport, or ship, by any means whatsoever, any such species taken in violation of subparagraphs (B) and (C);
- (E) deliver, receive, carry, transport, or ship in interstate or

- foreign commerce, by any means whatsoever and in the course of a commercial activity, any such species;
- (F) sell or offer for sale in interstate or foreign commerce any such species; or
- (G) violate any regulation pertaining to such species or to any threatened species of fish or wildlife listed pursuant to section 4 of the Act and promulgated by the Secretary pursuant to authority provided by this Act.

Section 10 allows for the granting of permits to undertake these prohibited acts if the object is for scientific purposes or to enhance the propagation or survival of a listed species.

ADDITIONAL BENEFITS

Recognition of species as threatened or endangered under the Act may lead to benefits to mollusk conservation that are not necessarily specified by law. For example, the U.S. Army Corps of Engineers, with the cooperation of the Fish and Wildlife Service, has produced a set of two posters that illustrate the unionids of the Upper Mississippi River to help commercial clam fishermen and others distinguish endangered species from other species in the region. The illustrations and biological data serve to educate the public about the richness of a fauna that they may previously have been unaware of.

Some states, such as Hawaii, add species to their state lists only after they are Federally listed. States, then, may not implement recovery measures unless there is Federal recognition of a species' status.

CONCLUSIONS

The Department of the Interior has recently proposed a priority system for allotting listing effort and research funds (Department of the Interior, 1981) to candidate species. This priority system ranks candidates according to degree of threat and their taxonomic group. Within each degree of threat (high, medium, or low) grouping, mollusks are ordered below all vertebrate classes, vascular plants, and insects. These rankings render unlikely the additional listing of mollusk species or funding of mollusk research during the 1982 fiscal year.

The Endangered Species Act of 1973, in spite of subsequent amendments and policy changes, retains a great potential for continuing protective measures for mollusks. Since personnel and funding for mollusk conservation under the Act are limited, public participation and funding for mollusk conservation, such as through the gathering of data and development of well-documented petitions, is needed. The extent of continued implementation of the Endangered Species Act to protect mollusks may well depend on the efforts of amateur and professional malacologists.

LITERATURE CITED

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AMU ANNUAL REPORTS

AMU ANNUAL BUSINESS MEETING

Friday, July 24, 1981
Fort Lauderdale, Florida

President Richard S. Houbrick called the annual business meeting of the American Malacological Union to order at 2 p.m. on Friday, July 24, 1981, in Board Rooms A & B of the Galt Ocean Mile Hotel at Fort Lauderdale, Florida.

Minutes of the 1980 annual meeting were printed in the 1980 Bulletin. With the correction to state that the publication of the survey on courses on malacology was prepared by Dr. Harold Harry, the minutes were approved.

Recording Secretary Constance E. Boone summarized the 1980 membership, noting that the first full year since the increase in dues showed the number of members remained the same. She announced that 73 new members had been enrolled during the first six months of 1981. Report approved. (Printed below in full)

Treasurer Myra L. Taylor summarized her report for fiscal year 1980, pointing out that the figures reflected the actual flow of income and disbursements from January through December. This report showed a profit of \$2030.07 for AMU in 1980. Report approved. (Full report printed below)

A summary of activities for 1980 by Corresponding Secretary Paul Jennewein was offered by Secretary Boone. Secretary Jennewein sent out publicity on this anniversary meeting and assisted the president in mailings to shell clubs, as well as answering inquiries on membership and other matters. He reported that he had sold \$513.50 of the AMU booklet, *How to Study and Collect Shells*. Report accepted. (Printed below in full)

A summary of the report to Council from Editor Dee Dundee was given by the Recording Secretary. The 1980 Bulletin had 108 pages, 16 more than the 1979 Bulletin, and printing and typesetting cost \$5,677.36, or \$52.57 a page. The total Bulletin cost was \$6,231.48, or \$6.23 each. This cost includes typesetting, printing, mailing, handling and Editor's expense. The Fall Newsletter cost \$441.69, and Dr. Dundee said the Spring Newsletter cost about the same. She remarked that postal costs would rise the next year. Report approved.

The meeting site for 1982 had already been approved for New Orleans, La. An update by Dr. Louise Kraemer, president-elect, reported that the meeting was scheduled to be held at the Fountain Bay Club July 19-23, 1982, that Dr. Dundee would act as local chairman, and that plans for the symposium on molluscan genetics were well underway. Dr. Kraemer asked members for input for the meeting.

Dr. Houbrick, in the absence of Dr. Alan Kohn, vice-president, discussed plans he had received by letter for the 1983 meeting. Dr. Kohn proposed that the meeting be held on the University of Washington campus in Seattle August 7-13, 1983, with housing

in the University dormitory facilities, the meetings probably to be held in the Student Union Building. He envisioned registration on August 7, with the sessions to begin on August 8. He planned field trips on August 10 and thought a week end trip to the Friday Harbor Laboratories might be arranged after the annual meeting. He was interested in having someone help organize symposia topics.

The motion brought from Council to accept the 1982 meeting report and to approve the 1983 meeting site and dates were accepted.

A report on the AMU Archives revealed that brand new space for AMU materials has been allotted at the Academy of Natural Sciences of Philadelphia. The Archives are healthy, growing, and thriving, according to Dr. William J. Clench and Dr. George Davis. Materials from this fiftieth anniversary meeting will be added to the Archives. Reports accepted.

Dr. Harold Murray, budget chairman, had written the budget approved at Council on the blackboard. In so doing, he announced, he had discovered that it was a deficit budget, a fact not realized at Council since it was not known that the summary figures had been totalled incorrectly. Dr. Murray noted, however, that the treasury was in good shape and that he had been conservative in income estimates. He felt the unbalanced budget would work out with no problem. Members approved the budget as presented. It follows:

INCOME

Memberships	\$ 7,700.00
(All types except life members)	
Sales	
HTSCS	500.00
Rare & Endangered Species reprint	20.00
Bulletin, Back Issues	600.00
Teskey Index	50.00
SUBTOTAL SALES:	<u>(\$ 1,170.00)</u>
Page Charges to Authors	2,000.00
Proceeds of Meeting	400.00
Donations, Symposium	1,000.00
Miscellaneous	<u>50.00</u>
TOTAL	\$12,320.00
Interest, Savings (Not added to income)	(400.00)

DISBURSEMENTS

Bulletin	6,720.00
Newsletter	880.00
Conservation Committee	50.00
Membership Committee	25.00
President's Organizing Fund	500.00
California Filing	5.00
Officers to Meetings	1,600.00
Legal Defense	50.00
Postage (except Bulletin and Newsletter)	800.00
Printing (except Bulletin and Newsletter)	550.00
Offices Supplies	100.00

Postal Permit	45.00
Miscellaneous	300.00
Annual Meeting Expense	150.00
Ads of Meetings and HTSCS, etc.	600.00
Memberships WSM, ASC, etc.	45.00
Symposia Subsidies	650.00
Student Prize (paper)	250.00
TOTAL	\$13,320.00
INCOME	\$12,320.00
DISBURSEMENTS	\$13,320.00
NET LOSS	\$ 1,000.00
INTEREST ON SAVINGS	\$400.00

Dr. Murray reported that the auditing committee found the books in excellent order. His report was accepted.

The slate of officers to be elected at this meeting and approved at Council was read by the Recording Secretary as follows:

President	Dr. Louise Russert Kraemer (one year term)
President-Elect	Dr. Alan Kohn (one year term)
Vice-President	Dr. Robert Robertson (one year term)
Treasurer	Mrs. Myra L. Taylor (three year term)
Councillors-At-Large	Dr. James Nybakken and Mr. Richard E. Petit (two year terms)

There were no other nominations, and the slate was accepted as presented. Dr. Clyde F.E. Roper served as chairman of the nominating committee, assisted by Drs. Tucker Abbott, Joseph Rosewater, Carol Stein and Alan Solem.

Other officers are in office—terms and include Recording Secretary, Constance E. Boone; Corresponding Secretary, Paul R. Jennewein; Publications Editor, Dr. Dee Dundee; Councillors-At-Large, John J. Jenkinson and William G. Lyons; Legal Advisor, H. Wallace Roberts.

Dr. Fred Thompson reported on the Monday meeting of the Council of Systematic Malacologists, noting that a constitution had been drafted for the first time and accepted at the meeting. Reports were made on publication of surveys and resources. Report approved.

A motion concerning the role of the Council of Systematic Malacologists in AMU was brought from Council and approved by members as follows: "The AMU supports the worthwhile goals and actions of the Council of Systematic Malacologists and shall pay reasonable dues of the Council of Systematic Malacologists to the Association of Systematic Collections. Furthermore, the Council of Systematic Malacologists shall function as a committee of the Executive Council of the AMU in those areas which affect the AMU."

Common Names Committee Chairman Dave Stansbery asked for input from members on establishing guidelines for possible publication of common names lists. (See additional action later in the meeting.)

The work to prepare a report on careers and opportunities in malacology will continue. A motion from Council requested that Dr. Tucker Abbott, committee chairman, contact Dr. Edwards of

the Association of Systematic Collections for information to be used in devising the AMU publication on jobs and career opportunities in malacology. Approved by members.

Dr. Houbbrick introduced two motions from Council on honorary life memberships by explaining that the Constitution provided for the allowance of 10 honorary life members and that due to deaths we had two spaces open. He mentioned that such memberships may be awarded on contributions to malacology and that retirement of candidates is not necessary criterion. Both candidates selected this anniversary year have made outstanding contributions to malacology and continue to do so.

The Recording Secretary announced unanimous approval at Council, as required by the Constitution, for naming Dr. Ruth D. Turner and Dr. R. Tucker Abbott honorary members of the American Malacological Union. She presented each name in motion separately and members voted approval.

A motion was brought from Council setting up a committee to assist the Editor. Members approved the action stating that the President form a committee including the Editor and two others to investigate the printing of the Bulletin—involving cost, quality and reprints. The action was approved and the committee would be set up by incoming President Kraemer.

Two motions approved by Council concerning conservation matters were approved as follows:

"The President is asked to appoint a committee to report to Council in 1982 on plans for a symposium on the nomenclature of mollusks used on the endangered and threatened list provided by the U.S. Fish and Wildlife Service."

"The AMU should write a letter to the State of California Department of Fish and Game urging further study and caution before they approve the widespread introduction of *Rumina decollata*."

Dr. Barry Roth read the following letter to be sent regarding *Rumina decollata*:

"We, the members of the American Malacological Union, write to express our concern over the intentional spread of the introduced Decollate Snail, *Rumina decollata*, in California. The Decollate Snail is being promoted as a predator and biological control agent on the Brown Garden Snail, *Helix aspersa*, but the following considerations, based on experience in southwestern states, deserve attention:

1. *Rumina* often achieves very large numbers and becomes a nuisance or horticultural pest in its own right.
2. The fact that dense populations of *Rumina* and *Helix aspersa* can coexist indefinitely suggests limited validity to the claim of *Rumina* as a biological control on *Helix*; and
3. Upon escape from cultivated areas, *Rumina* may impact adversely by competition and predation upon the harmless and valuable native snails of California.

We support the present restrictions on release and transport of the Decollate Snail into regions of the state where it is not already established, and urge inquiry into the need for additional measures to limit the dissemination of this species."

A call for the other business brought information from Dr.

Abbott that the committee on common names had met during the week and that it was felt there would be considerable cost in printing and distributing such a list. He requested some input from members on financing the project. After discussion on methods to finance the project, members voted the following motion:

"The chairman of the Common Names Committee is empowered to explore sources of grant proposed must be approved by the President and Treasurer of the AMU prior to submittal to the agency or agencies involved."

Announcements on the Saturday field trips were made. Gene Everson, meeting chairman, announced that the auction had raised \$2,986.60. (Note: The final figure from the auction reached \$3,147.60!) This money goes into the symposium fund.

Dr. Houbrick announced that extra programs from this anniversary

sary meeting would be available at the registration desk for \$1.00 each.

He reported that Mrs. Selma Lawson, a registrant at the meeting, was recovering from an operation on her hip in a local hospital. (She had fallen on Monday night of the meeting.) AMU had gifted her with Alison Kay's book *Hawaiian Seashells*. Dr. Houbrick also announced that the special cancelled envelopes and the anniversary stamp cards arranged for this meeting by Dick Petit had been mailed to Honorary Life President Stillman Berry and to those honorary life members not present.

There was no other business. The meeting adjourned at 3 p.m.

Respectfully submitted,
Constance E. Boone, Recording Secretary

REPORT OF THE TREASURER

CHECK BOOK BALANCE, JANUARY 1, 1980			\$ 7,495.51
RECEIPTS:			
Memberships:			
Regular	\$5,624.45		
Sustaining	70.00		
Corresponding	275.50		
Clubs & Institutions, Domestic	873.50		
Clubs & Institutions, Foreign	143.50		
Subscribing	<u>192.00</u>	7,178.95	
Sales:			
HOW TO STUDY & COLLECT SHELLS	603.00		
RARE & ENDANGERED SPECIES	16.50		
TESKEY INDEX	45.00		
BULLETIN, Back Issues	<u>659.38</u>	1,323.88	
Page Charges To Authors	2,278.75		
Symposium Donations	789.00		
Miscellaneous Credits	115.50		
Louisville, Ky., Meeting	344.43		
Louisville Auction for Symposium Fund	<u>1,673.86</u>	5,201.54	
Total Receipts From All Activities		<u>13,704.37</u>	<u>13,704.37</u>
TOTAL CASH ACCOUNTED FOR:			
DISBURSEMENTS:			
BULLETIN, Inc. Printing, Postage, Etc.	4,812.50		
NEWSLETTER, Inc. Printing, Postage, Etc.	1,051.18		
President Roper's Expenses	559.60		
Other Postage	673.72		
Other Printing	431.45		
Office Supplies	76.61		
Adding Machine Repair	29.50		
President Houbrick's Expenses	8.00		
California Filing Fees	7.50		
Symposium Expenses	1,700.00		
Dues To Others	45.00		
Officers' Expenses To Meeting	1,700.65		
Ads For Meeting	381.60		
Refunds, Bank Charges, Bad Checks	91.82		
Miscellaneous Disbursements	378.18		
Transferred To Savings Account	<u>3,000.00</u>	14,947.31	
Total Disbursements From All Activities		<u>14,947.31</u>	<u>14,947.31</u>
CHECK BOOK BALANCE ON DECEMBER 31, 1980		6,252.57	
TOTAL CASH ACCOUNTED FOR:			\$21,199.88

REPORT OF THE TREASURER

SASA* Savings Account #5-034514	\$4,715.02	
Interest Added	273.01	
Transfer From Checking	<u>3,000.00</u>	
Total For Account	7,988.03	7,988.03
SASA* Savings Certificate #5-904812 (Life Membership Fund)	2,768.81	
Interest Added	<u>185.95</u>	
Total For Account	2,954.76	2,954.76
TOTAL SAVINGS		<u>10,942.79</u>

*SASA = San Antonio Savings Association

RECAPITULATION OF ASSETS, DECEMBER 31, 1980:

Cash in Checking Account, Mercantile Bank	\$6,252.57
Treasurer's Petty Cash	20.00
Secretary's Petty Cash	175.00
SASA* Account #5-034514	<u>7,988.03</u>
TOTAL ASSETS:	<u>\$14,435.60</u>

LIFE MEMBERSHIP SAVINGS ACCOUNT #5-904812

\$2,954.76

AMU NET WORTH, DECEMBER 31, 1980:

\$14,435.60

CHANGES IN CAPITAL ACCOUNT:

AMU Capital Account, January 1, 1980	12,405.53
AMU Capital Account, December 31, 1980	<u>14,435.60</u>
NET INCREASE IN ASSETS IN 1980	<u>\$2,030.07</u>

Respectfully Submitted,
Myra L. Taylor, Treasurer

REPORT FROM THE RECORDING SECRETARY

The state of membership in the fiscal year of 1980 was good. We made no gains, mainly due to the loss of family members in that membership category, but we also did not lose members in this first report of a year reflecting the raise in dues.

Membership for 1980 fiscal year is as follows:

Honorary Life President	1
Honorary Life Members	8
Life Members	27
(no loss but one now honorary life)	
Regular Members (Western Hemis.)	524
Family Members	72
Sustaining Members	1
Corresponding Members (Outside W.H.)	16
Affiliated Institutions, etc.	54
Clubs, Regional Organizations	<u>37</u>
Total	740
Subscriptions	8

As of July 10, 1981, we had enrolled 73 new members—one sustaining and 10 reinstatements. Sustaining memberships add unrestricted funds to the treasury. We have six in 1981. We note six resignations for 1981, and we have four deaths to report since the 1980 Bulletin In Memoriam list.

Despite the fact that the treasurer billed first class dues notices

last Fall and has already sent out second notices this year, we still have 98 memberships not paid in 1981.

Sales of old Bulletins in 1980 were very good. We answer all inquiries about AMU publications. We continue to advertise what we have available. We are grateful for donations of old Bulletins. Dr. Tucker Abbott gave us 46 Bulletins in 1980. We urge members to give us old issues to help AMU (a tax deduction may be made by donors). Some issues are needed to complete library orders.

Expenses for the business of this office in 1980 were \$398.27, an increase from 1979 due to the rise in postal costs. We are now mailing (book rate) new members gifts of the current Bulletin and How to Study and Collect Shells as approved last year.

New membership letters were printed in 1980. We will update the postal fees on the application forms in 1982 due to increased charges for mailing outside the U.S. zones.

Reminders to members to update addresses are constant from this office. We had less than 10 Bulletins returned this year. Newsletters are not being sent out with return address requests at this time and are lost to members who move without telling us.

Respectfully submitted,
Constance E. Boone
Recording Secretary

REPORT OF THE CORRESPONDING SECRETARY

During the past year, 295 books — copies of "How to Study and Collect Shells" — were mailed out or delivered to shops, agencies and individuals. Sales of these books totaled \$513.50.

Replies during this period cost \$220.01 in postage and \$83.39 in printing.

An advertisement on the AMU's forthcoming meeting was prepared and sent to a leading scientific publication; other publications gratefully provided news announcements of the meeting. I

sent these suggested copy.

Letters from Europe seeking information seem to be increasing, with many asking us to send "How to Study and Collect Shells" which they understand to be free. In about half or a third of the cases, the writers send checks after we notify them of the cost and postage options. Sending the book air mail is almost as much as the cost of the book.

Respectfully submitted,
Paul R. Jennewein
Corresponding Secretary

THE AMERICAN MALACOLOGICAL UNION, INC.

Active Members 1981

(Membership List Revised October 20, 1981)

Abbott, Dr. R. Tucker, P.O. Box 2255, Melbourne, FL. 32901.
Adler, Dr. Howard, 116 Edgewood Drive, Bridgewater, N.J. 08807 (Marine-radiography)

Aguayo, Dr. Carlos G., Dept. of Biology, Univ. of Puerto Rico, Mayaguez, Puerto Rico 00708.

Ahlstedt, Steven, 11 East Norris Road, Norris, TN. 37828 (Biological aide, Fisheries management, TVA).

Albert, Ernest and Bernice, 905 S. Bayshore Blvd., Safety Harbor, FL. 33572.

Alexander, Robert C., 423 Warwick Road, Wynnewood, PA. 19096.

Allen, James E., 1108 Southampton Dr., Alexandria, LA. 71301 (Tertiary micro-mollusca).

Allen, Dr. J. Frances, 7507 23rd Ave., Hyattsville, MD. 20783.

Allen, Mrs. Lawrence K. (Betty), Box 822, Port Isabel, TX. 78578 (*Murex*, *Pecten*, world marines; owner, Shop of the Seven Seas).

Allen, Miss Letha S., 187 Argyle St., Yarmouth, Nova Scotia, Canada B5A 3X2 (General).

Amaratunga, Mr. Tissa, Dept. Fisheries and Oceans, Resource Branch, Box 550, Halifax, Nova Scotia, Canada B3J 2S7 (Life history, biology and management of Cephalopods).

Anders, Kirk W., Shells of the Seas, Inc., P.O. Box 1418, Ft. Lauderdale, FL. 33302 (Volutidae; all rare shells).

Anderson, Carleton Jay, Jr., 56 Kettle Creek Rd., Weston, CT. 06883.

Andrews, Dr. Jean, 6615 LaConcha Pass, Austin, TX. 78749.

Armington, Stewart and Lee, 15932 Brewster Rd., Cleveland, OH. 44112 (Shells with postage stamps and worldwide marine).

Ashbaugh, Karen, El Paso Community College, Box 20500, El Paso, TX. 79998.

Ashwell, James R., P.O. Box 555, Windermere, FL. 32786 (General).

Athearn, Herbert D., Museum of Fluvial Mollusks, Rt. 5, Box 499, Cleveland, TN. 37311 (Freshwater mollusks).

Athearn, Mrs. Roy C. (Eleanor), 5105 N. Main St., Fall River, MA. 02720 (Land shells).

Auffenberg, Kurt, Florida State Museum, Univ. of Florida, Museum Road, Gainesville, FL. 32611 (Neritacea; Neritidae).

Avellanet, Mrs. Helene, 105 Clipper Way, Fair Winds Villas, Nokomis, FL. 33555.

Avery, Mrs. R. Gail, Box 2557, Harbor, OR. 97415 (West American mollusks; exchange).

Aviles E., Prof. Miguel C., Apartado 6-765, Zona Postal El Dorado, Panama, Rep. of Panama (Histology and embryology).

Babarakzai, Dr. Noorullah, Dept. of Biology, Central Missouri State Univ., Warrensburg, MO. 64093.

Baerreis, David A., Dept. Anthropology, Social Science Bldg. Univ. of Wisconsin, Madison, WI. 53706 (Paleoecological interpretation through mollusks).

Baker, Mrs. Horace B., 11 Chelton Rd., Havertown, PA. 19083.

Bankston, Dr. Cecil N., Jr., 4841 Woodlake Dr., Baton Rouge, LA. 70816 (Collector of marine shells).

Bargar, Tom and Denise Schneider-Bargar, 320 S. Beltline Blvd., Apt. 31-D, Columbia, S.C. 29205 (Functional morphology of gastropods).

Barlow, Mrs. G. Barton, 76 Westervelt Ave., Tenafly, N.J. 07670.

Batten, Dr. Roger L., American Museum of Natural History, Central Park West at 79th St., New York, N.Y. 10024 (Fossil and recent Pleurotomarians).

Bauer, Laura M., 2126 45th St., Galveston, TX. 77550 (All mollusks).

Baum, Newman N., 83 Weaving Lane, Wantagh, N.Y., 11793.

Bazata, Kenneth R., 221 Oakcreek Drive, Lincoln, NE, 68528 (Terrestrial pulmonates; *Dentalium*).

Beetle, Ms. Dorothy E., Director, Patterson Planetarium, 2900 Floyd Road, Columbus, GA. 31907 (U.S. land and fresh water mollusks).

Bequaert, Dr. Joseph C., 24 Berkshire Terrace, Amherst, MA. 01002.

Bergmann, Joseph A., Rt. 3, Box 3064, Boerne, TX. 78006 (Land and freshwater mollusks, recent and fossil).

Bermudez, Alejandro, P.O. Box 68, Missouri City, TX. 77459 (*Murex* and Nudibranchs from the Caribbean zone).

Berry Dr. Elmer G., 8506 Beech Tree Court, Bethesda, MD. 20034.

Berry, Dr. S. Stillman, 1145 W. Highland Ave., Redlands, CA. 92373.

Bianchi, Mr. and Mrs. Robert, Box 235, Goodland, FL. 33933.

Bickel, David, 613 W. Ave. C, Bismarck, N.D. 58501 (Systematics and ecology of freshwater mollusks, esp. Pleurocent snails).

Bijur, Jerome M., 135 Seventh Ave. N., Naples, FL. 33940 (Buy, exchange Florida, Caribbean and Gulf of Mexico).

Bippus, Emma Leah, 2743 Sagamore Rd., Toledo, Ohio, 43606 (Marine gastropods).

Bishof, David, 994 68th St. Ocean, Cayo Vaca, FL. 33050.

Bishop, Thomas Dale, Dept. of Biology, Univ. of Southwestern Louisiana, Lafayette, LA. 70504 (Ecology related to gastropods).

Blair, Lucianne, 1033 Rockcreek Drive, Port Charlotte, FL. 33952.

- Blaisten, Dr. Lia O.B. de, Laboratorios Bioquímex, S.A. de C.V., Nicolas San Juan 1535, Colonia del Valle, Mexico 12, Mexico (Scientist amateur—American and Caribbean seashells; cowries and *Strombus*).
- Bleakney, Dr. J. Sherman, Dept. of Biology, Acadia Univ., Wolfville, Nova Scotia, Canada BOP 1X0 (Nudibranchs and sacoglossans; ecology, zoogeography, systematics).
- Bledsoe, William D., 352 Bon Hill Rd., Los Angeles, CA. 90049.
- Body, Ralph L., 2538 10th Ave. W., Seattle, WA. 98119. (Taxonomy).
- Bogan, Arthur E., Dept. of Malacology, ANSP, 19th and the Parkway, Philadelphia, PA. 19103.
- Boone, Constance and Hollis, 3706 Rice Blvd., Houston, TX. 77005.
- Bond, Miriam, 111 Sheldon, Ames, Iowa 50010 (Limpets).
- Boss, Dr. Kenneth Jay, MCZ, Harvard University, Cambridge, MA. 02138.
- Bottimer, L.J., Rt. 1, Box 205, Tow, TX. 78672 (Recent and fossil mollusks).
- Bowers, Raymond E. and Sylvia G., 128 E. Oakland Ave., Columbus, OH. 43201 (Freshwater ecology of Naiades).
- Boyd, Dr. and Mrs. Eugene S., 6806 Gillis Rd., Victor, N.Y. 14564 (All aspects of Phylum Mollusca).
- Brakoniecki, Thomas F., RSMAS, 4600 Rickenbacker Causeway, Miami, FL. 33149 (*Cephalopoda*).
- Brand, Dr. Timothy, Scripps Institution of Oceanography A-027, La Jolla, CA. 92093 (Eulimid gastropods parasitic on/in marine organisms).
- Brandauer, Mrs. Nancy E., 1760 Sunset Blvd., Boulder, CO. 80302.
- Branson, Dr. Branley A., P.O. 50, Eastern Kentucky Univ., Richmond, KY. 40475.
- Bratcher, Mrs. Twila, 8121 Mulholland Terrace, Hollywood, CA 90046.
- Britton, Dr. Joseph C., Dept. of Biology, Texas Christian Univ., Ft. Worth, TX. 76129.
- Brocco, Dr. Steven Louis, (Cephalopod biology, Dept. of Oral Biology, Univ. of Wash., Seattle, Wash. 98195).
- Brown, Drs. Harvey and Marjorie T., 9455 S.W. 81st Ave., Miami, FL., 33156.
- Broyles, Mrs. Catherine E., 5701 Fairfield Ave., Ft. Wayne, IN. 46807.
- Brunson, Dr. Royal Bruce, 1522 34th St., Missoula, MT. 59801.
- Buchanan, Alan, Missouri Dept. of Conservation, Fish & Wildlife Research Ctr., 1110 College Ave., Columbia, MO. 65201 (Fisheries biologist).
- Buckley, George D., 164 Renfrew St., Arlington, MA 02174.
- Burch, Dr. John B., P.O. Box 2749, Ann Arbor, MI. 48106 (Land and fresh water mollusks).
- Burch, Mrs. John Q., 1300 Mayfield Rd., Apt. 61-L, Seal Beach, CA. 90740.
- Burch, Dr. Torn and Beatrice L., P.O. Box 309, Kailua, Hawaii 96734. (BLB, planktonic mollusks; TAB, deep water mollusks).
- Bucher, Anita P., 7504 Branchwood Drive, Mobile, AL. 36609 (Taxonomy).
- Burgess, Charles, 8902 Tolman Road, Richmond, VA. 23229 (Volutes, worldwide).
- Burger, Sybil B., 3700 Gen. Patch N.E., Albuquerque, NM 87111 (Gulf of Mexico; land snails).
- Burke, Mrs. Patricia, 18128 Lakeside Lane, Nassau Bay, TX 77058.
- Burky, Dr. Albert J., Dept. of Biology, Univ. of Dayton, Dayton, OH. 45469.
- Butler, Nancy M., Dept. of EPO Biology, Univ. of Colorado, Boulder, CO. 80309.
- Cake, Dr. Edwin W., Jr., Head, Oyster Biology Station, Gulf Coast Research Laboratory, East Beach, Ocean Springs, MS. 39564.
- Caldwell, Dr. Ronald S., Kentucky Nature Preserves Commission, 407 Broadway, Frankfort, KY. 40601 (Terrestrial gastropods of Kentucky).
- Call, Sam M., 107 Goodrich Ave., Lexington, KY. 40503 (Pelecypods).
- Calnan, Thomas R., Univ. of Texas Bureau of Economic Geology, University Station Box X, Austin, TX. 78712 (Gulf Coast mollusks).
- Campbell, Mr. and Mrs. Donald C., 3894 DuPont Circle, Jacksonville, FL., 32205 (General collecting).
- Capo, Thomas R., 59 Nickerson St., Falmouth, MA. 02536 (Benthic Ecology).
- Cardeza, R. Adm. and Mrs. Carlos M. Dec. to Mar. 29, P.O. Box 6746, Houston, TX. 77005; April 1 to Nov. 30, 1718 Jewel Box Dr., Snailbel, FL. 33957 (Florida and Texas shells).
- Carlton, James T., Woods Hole Oceanographic Institution, Woods Hole, MA., 02543 (Estuarine and brackish water mollusks.).
- Carney, Cdr. W. Patrick, MSC USN, Naval Medical Research and Development Command, National Naval Medical Center, Bethesda, MD. 20014.
- Camiker, Prof. Melbourne R., College of Marine Studies, Univ. of Delaware, Lewes, DE. 19958.
- Carroll, Susan E., 32-03 150 St., Flushing, N.Y. 11354 (Parasitology in marine mollusks).
- Carson, John and Laura W., 221 Elm Ave., Morrisville, PA. 19067.
- Castagna, Michael, Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Pelecypod larval behavior).
- Cate, Jean M., P.O. Drawer 710, Rancho Santa Fe, CA. 92067 (*Mitra*, *Cypraea*; no exchanges).
- Chadwick, Albert F., 2607 Turner Rd., Wilmington, DE. 19803 (Marine shells).
- Chambers, Dr. Steven, Office of Endangered Species, U.S. Fish and Wildlife Service, Dept. of the Interior, Washington, DC 20240.
- Chanley, Mr. and Mrs. Paul, P.O. Box 12, Grant, FL. 32949.
- Chappell, Mrs. Elaine, 2435 Dunloe Drive, Dallas, TX. 75228 (All mollusks).
- Chichester, Lyle F., Dept. Biol. Sciences, Central Conn. State College, 31 Chamberlain St., New Britain, CT. 06052 (Ecology of terrestrial gastropods, biology of land slugs).
- Christensen, Carl C., 1612 Kamole St., Honolulu, HI. 96821.
- Christie, Dr. John D., Dept. of Pathology, Univ. of Texas Medical Branch, Galveston, TX. 77550.
- Chrosiecchowski, Przemyslaw K., APTDO 125, Maracay, Venezuela, 2101A (Planorbidae).
- Chung, Daniel, Museum of Zoology, University of Michigan, Ann Arbor, MI. 48104 (Pulmonates; Hawaiian mollusks).
- Clarke, Dr. Arthur H., Ecosearch, Inc., 7 Hawthorn St., Mattapoisett, MA. 02739.
- Clench, Dr. William J., 26 Rowena St., Dorchester, MA. 02124 (Land shells in all of the West Indies; fresh water mollusks in North America).
- Clover, Philip W., P.O. Box 83, Glen Ellen, Ca. 95442 (Rare *Cypraea*, *Conus*, *Volva*, *Murex*, *Marginella* — Buy and exchange).
- Clymer, George M., Minnesota Dept. of Natural Resources, Ecological Services Section, Box 25, 658 Cedar St., St. Paul, MN. 55155 (*Unios*).
- Coan, Dr. Eugene V., 891 San Jude Ave., Palo Alto, CA. 94306.
- Cole, Timothy James, Horn Point Environmental Laboratory, Univ. of Maryland, Box 775, Cambridge, MD. 21613 (Genetic divergence among molluscan populations; ecological-genetic interdigitations).
- Coleman, Dr. Richard W., Dept. of Biology, Prof. of Science and Head, Upper Iowa University, Fayette, IA. 52142 (Environmental Interrelationships, plants-invertebrates).
- Colmenares, Raul Peraza, Lra transversal de Sebuca, Quinta "Don Raul", Caracas, Venezuela, 107 (Taxonomy and effects of pollutants on mollusks).
- Compitello, Mrs. Juliette, 5630 Alta Vista Rd., Bethesda, MD 20034.
- Conde, Vincent, McGill University (Redpath Museum), Montreal Canada H10.
- Coney, Cliff, Dept. of Biology, Coastal Carolina College, Univ. of South Carolina, Conway, S.C. 29526 (Evolution biology of terrestrial and freshwater mollusks).
- Cook, Bunnie and George, 1120 Makaiwa St., Honolulu, Hawaii 96816 (Marine-Mitridae and other families).
- Cook, Dr. Susan B., Dept. of Zoology, The Ohio State University, 1735 Neil Ave., Columbus, OH. 43210 (Behavioral ecology of tropical marine gastropods; behavioral ecology of freshwater gastropods).
- Cooper, Robert W., 5012 Pfeiffer Rd., Peoria, IL. 61607 (Florida marine; world *Murex*, *Pecten*, *Spondylus*, *Scuba*).

- Conklin, William A., R.T. (FASRT); President, Inner Dimension, 1571 Marshall Ave., Orangeburg, S.C. 29115 (Radiography/photography).
- Coovert, Gary A., Curator of Biology, Dayton Museum of Natural History, 2629 Ridge Ave., Dayton, OH. 45414 (Taxonomy, phylogeny, esp. Marginellidae, Bursidae: micromollusks).
- Corgan, Dr. James X., Dept. of Geology, Austin Peay Univ., Clarksville, TN. 37040 (*Pyramidellidae*, *Vitrinellidae*, *Scaphopods*, *Tertiary faunas*).
- Cornély, Guy, 53 rue Jean-Jaures Raizet, Abymes, Guadeloupe, French West Indies.
- Corpening, John T., 324 NE 81st St., Seattle, WA. 98115 (Marine coral dwelling gastropods).
- Cosman, Dieter, 7 Oak Hill Rd., Huntington, N.Y. 11743 (Marine tropical and subtropical Gastropoda and Bivalvia worldwide).
- Covey, Jewell M., 5666 E. Hampton, Apt. 270, Tucson, AZ. 85712 (Panamic Province, all mollusks, and *Epitonicea*, worldwide, Calif. and Northwest mollusks).
- Craine, Mrs. Ruth A., P.O. Box 2001, Southern Pines, NC 28387.
- Cramer, Frances L., 766 Obispo Ave., Long Beach, CA 90804 (Ecology; conservation).
- Crissinger, Myrna May and William (Bill), 820 North Court Street, Crown Point, IN. 46307.
- Croft, Mrs. Thomas L., Box 7, Captiva, Is., Fla. 33924
- Cull, Alice J., 7927 Chippewa Rd., Brecksville, OH. 44141.
- Cummings, Raymond W., 37 Lynacres Blvd., Fayetteville, NY. 13066 (Shells of the West Indies shells, esp. Windward and Grenadine Is.).
- Curtis, Mary Ann, 5431 Queensloch, Houston, TX. 77096.
- Cutler, Henry H., 105 Abbott Rd., Wellesley Hills, MA. 02181.
- Cvancara, Dr. Alan Milton, Dept. Geology, Univ. of N. Dakota, Grand Forks, ND. 58202 (Pleistocene and Holocene continental mollusks, early Tertiary continental and marine mollusks).
- Danforth, Louise L., 1241 Lake Ave., Apt. D., Metairie, LA. 70005.
- Darcy, George H., Univ. of Miami School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Davenport, Mrs. Lillian B., 802 Cape Ave., Box 81, Cape May Point, NJ. 08212 (Conchology, malacology, anything pertaining to the sea).
- Davis, Dr. Derek S., Nova Scotia Museum, 1747 Summer St., Halifax, NS, B3M 3A6 Canada (Gastropod biology and taxonomy).
- Davis, Dr. George M., Academy of Natural Sciences of Philadelphia, 19th and the Parkway, Philadelphia, PA. 19103.
- Davis, Dr. John D., 25 Old Homestead Rd., P.O. Box 156, Westford, MA. 01886 (Ecology of marine bivalves).
- Davis, Robert N., 1309 Hedgelawn Way, Raleigh, N.C. 27609 (Interested in promoting the survival of systematic mollusk collections and institutions).
- Deatrick, Paul A., 218 S.W. 32 Ave., Miami, FL. 33135 (*Strombus*, *Busyon*).
- de Graaff, Gerrit, 10915 S.W. 55 St., Miami, FL. 33165.
- Deisler, Jane E., Zoology Dept., Univ. of Florida, Gainesville, FL. 32611. (Systematics of tropical land snails).
- DeLuca, Mrs. Theresa and Ms. Gladys, 61 Deborah Rd., Hanover, MA. 02339.
- Demond, Miss Joan, 202 Bicknell Ave., #8 Santa Monica, CA. 90405.
- Dennis, Ms. Sally D., Box 402, Shawsville, VA. 24162 (Freshwater mussels).
- Dexter, Miss Norma, 150 Barker Hill Dr., RFD 3, Guildford, CT. 06437 (*Cypraea*).
- Dexter, Dr. Ralph W., Dept. Biological Science, Kent State Univ., Kent, OH. 44242.
- Deynzer, Albert E. and Beverly A., Showcase Shells, 1614 Periwinkle Way, Sanibel, FL. 33957 (Marine mollusks).
- Dietrich, Mr. and Mrs. Louis E., 308 Veri Dr., Pittsburgh, PA. 15220.
- Dilley, Donald R., Rm. 304, 1220 N. Street, Dept. of Food and Agriculture, State of Calif., Sacramento, CA. 95814 (Mollusks of economic importance to agriculture).
- Dillon, Robert T., Jr., Dept. of Malacology, ANSP, 19th and the Parkway, Philadelphia, PA. 19103.
- DiMatteo, Tony, 556 NW 55 St., Boca Raton, FL. 33432 (Opistho-
- branch and gastropod defensive mechanisms, predator-prey interactions).
- Dolin, Eric, 107 Briar Brae Rd., Stamford, CT. 06903 (*Conus*, *Cypraeidae*, *Strombus*, *Voluta*).
- Doyle, Miss Patricia, 336 Pine Ave., St. Lambert, Quebec, Canada J4P 2N8 (Collector).
- Draper, Bertram C., 8511 Bleriot, Los Angeles, CA. 90045 (Eastern Pacific minute mollusks and all Western U.S. marine mollusks).
- DuBar, Dr. and Mrs. Jules R., Rt. 1, Box 70, Morehead, KY. 40351 (Cenozoic and recent mollusks—ecology and Paleoecology).
- Dundee, Dr. Dee S., Dept. of Biological Sciences, Univ. of New Orleans, Lakefront, New Orleans, LA. 70122 (Land mollusks, freshwater mussels).
- Dvorak, Stanley J., 3856 W. 26th St., Chicago, IL. 60623 (Muricidae).
- Eddison, Grace G., M.D., "Wildwood," Rt. 4, Carlisle, KY. 40311.
- Edwards, D. Craig, Dept. of Zoology, Morrill Science Center, Univ. of Massachusetts, Amherst, MA. 01003 (Population ecology and behavior of marine benthic mollusks).
- Emberton, Kenneth C., Committee on Evolutionary Biology, Univ. of Chicago, Chicago, IL. 60637 (Land snails).
- Emerson, Dr. William K., American Museum of Natural History, Central Park West at 79th St., New York, NY. 10024.
- Eng, Dr. Larry L., Invertebrate Biologist, Endangered Species Program, Inland Fisheries Branch, Calif., Dept. of Fish and Game, Sacramento, CA. 95616.
- Enright-Huff, Dan and Ms. Peggy, 1601 Eastcrest Drive, Apt. #L-2, Charlotte, N.C. 28205 (Scallops, tun, whelk, conch).
- Erickson, Carl W., 4 Windsor Ave., Auburn, MA. 01501.
- Eubanks, Dr. Elizabeth R., 57 Lyall St., West Roxbury, MA. 02132 (Florida marine shells).
- Evans, Miss Susan E., 244 Congress Ave., Lansdowne, PA. 19050 (*Conus*, *Cypraea*, *Murex*).
- Eversole, Dr. Arnold G., Dept. of Entomology, Clemson Univ., Clemson, SC. 29631. (Interpopulation variation and bioenergetics of molluscan populations).
- Everson, Gene D., 5224 Northwest 17th Court, Lauderhill, FL. 33313 (Worldwide collection with emphasis on Florida, Caribbean and miniatures).
- Fairbanks, Dr. H. Lee, Penn State University, Beaver Campus, Brodhead Road, Monaca, PA. 15061 (Systematics of land gastropods; genetic variability of land gastropods).
- Fallo, Glen Jay, 1706 Hill Rise Drive, Apt. 8, Lexington, KY. 40504 (Freshwater mussels (Ohioan fauna)).
- Feber, Olive M., 4777 Sandia, Los Alamos, N.M. 87544 (Cones and cowries).
- Fechtner, Frederick R., 2611 W. Fitch Ave., Chicago, IL. 60645.
- Feinberg, Harold S., Dept. of Fossil and Living Invertebrates, AMNH, Central Park West at 79th St., N.Y., NY. 10024 (Polygyridae and other U.S. Pulmonata).
- Ferguson, Dr. and Mrs. John H., 226 Glandon Dr., Chapel Hill, NC. 27514.
- Fieberg, Mrs. Kleinie, 1430 Lake Ave., Wilmette, IL. 60091.
- Finlay, C. John, 116 Tanglewood Lane, Nottingham Manor, Newark, DE. 19711 (Marine mollusks Western Atlantic and Caribbean).
- Foehrenback, Jack, 91 Elm St., Islip Manor, NY. 11751 (Ecology of marine mollusks).
- Fontanier, Dr. Charles E., P.O. Box 2023, Tulsa, OK. 74101 (*Cypraeidae*; *Unionidae*; *Scuba*; *Ecology*).
- Foote, Miss Mary K., 16204 Diana Lane, Apt. 322A, Houston, TX. 77062 (Land snails and self-collected miniatures of the Texas coast).
- Foster, Mrs. Fred H., 401 N. Justus St., Oxford, IN. 47971 (General).
- Fowden, (Mrs.) Jeanne B., 444 54 Whispering Pines Dr., Scotts Valley, CA. 95066 (Limpets; sand dollars).
- Franzen, Dr. Dorothea, Science Programs, Illinois Wesleyan Univ., Bloomington, IL. 61701.
- Freitag, Thomas M., 13602 137th Ave. West, Taylor Ridge, IL. 61284 (Freshwater mussels, especially endangered species; freshwater and terrestrial gastropods).
- Frye, Mark W., 679 S. Reed Court, Lakewood, CO. (Naiads, Micropalaeontology with specialty in Ordovician micro-mollusks).

- Fuess, Thomas, 6978 Pickadilly Ct. SW, Ft. Myers, FL., 33907 (Southwest Florida coast and Florida Keys mollusks).
- Furbish, Dean R., Wings Nolk, Paris, KY. 40361. (Behavior, physiology of mollusks).
- Galindo, Lic, Ernesto Santos, Jorge Elliot #12, Colonia Polanco, 70 Piso, Mexico, D.F.5.
- Garcia, Dr. Emilio Fabian, 115 Oak Crest Dr., Lafayette, LA. 70503 (Gulf of Mexico and Caribbean mollusks).
- Gardner, L.E. (Lu), 2425 N. Bartlett, Milwaukee, WI. 53211.
- Gardner, Mrs. Sandra M., 1755 Univ. Ave., Palo Alto, CA. 94301 (Vermetidae).
- Gerberich, Andrew G., 5029 South 23rd St., Arlington, VA. 22206 (Fresh water mussels).
- Gerhold, Robert M., senior microbiologist, Nalco Chemical Co., 1801 Diehl Rd., Naperville, IL. 60540 (Environmental physiology and mollusk pest control).
- Germer, John and Dorothy, 653 Briardcliff Ave., Maywood, NJ. 07607 (John, photography of shells; Dorothy: *Pectens*, *Murex* and shells of the Eastern and Western Atlantic).
- Germon, Mrs. Raye N., 27 Rosemont Dr., Gaithersburg, MD. 20760 (Muricidae, Volutidae, Mesozoic and Paleozoic fossils (marine)).
- Gibbons, Ms. Mary C., Marine Sciences Research Center, State Univ. of New York, Stony Brook, N.Y. 11794.
- Gilbert, Dr. William H., Dept. Biology, Simpson College, Indianola, IO. 50125 (Marine and freshwater bivalves — ecology, behavior, systematics; *Tellina*, *Macoma*).
- Gill, Richard W., 4348 Rider Trail, Earth City, MO. 63045 (Riverine Pelecypoda).
- Gilmour, Dr. Thomas H.J., Dept. Biology, Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0 (Ansimoyarian bivalves).
- Girardi, Dr. Elizabeth-Louise, 707 Kent Rd., Kenilworth, IL. 60043.
- Goethel, Bessie G., 9402 Nona Kay Dr., San Antonio, TX. 78217 (*Cypraea* — buy and trade).
- Goldberg, Richard L., 49-77 Fresh Meadow Lane, Flushing, NY. 11365 (Worldwide marine and land shells — collector and dealer — Hawaiian *Achatinella* tree snails).
- Golden, Myrna, 690 Hungry Harbor Rd., North Woodmere, N.Y. 11581 (Marine).
- Golightly, Charles Grady Jr. and Nancy Hamill, 1505 Lemon Tree Lane, College Station, TX. 77840 (Bivalve ecology/systematics).
- Goodfriend, Glenn A., Zoology Dept., Univ. of Florida, Gainesville, FL. 32611 (Molluscan ecology).
- Gordon, Mackenzie Jr., Paleontology and Stratigraphy Branch, U.S. Geological Survey, Smithsonian, Washington, D.C. 20560.
- Gordon, Mark E., Dept. of Zoology, S.E. 632, Univ. of Arkansas, Fayetteville AR. 72701 (Freshwater mollusks, mollusks of Arkansas, mollusks of the Ozarks).
- Gray, Susan and Dan Marelli, Dept. of Biological Sciences, Florida State University, Tallahassee, FL. 32306.
- Greenberg, Mrs. Janis, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greenberg, Mrs. Ruth, 22762 Pacific Coast Hwy., Malibu, CA. 90265 (Tidepool Gallery).
- Greer, W.J., 13635 Butterfly Lane, Houston, TX. 77079 (Western Pacific and Australian Great Barrier Reef mollusks).
- Groat, Mrs. Cynthia S., Marine Laboratory, Dept. Biological Sciences, Bowling Green State Univ., Bowling Green, OH 43403 (General marine biology; recently acquired Bippus shell collection from Mrs. Alvin Bippus of Toledo, Ohio).
- Gruber, Gregory L., College of Marine Studies, University of Delaware, Lewes, DE. 19958 (Reproduction, Physiology).
- Guckert, Richard H., 1757 Kimberly Dr., Marietta, GA. 30060 (Systematics of freshwater mussels; ecology, seasonal life histories of freshwater mollusks; comparative ecology and physiology of Nassariidae).
- Gugler, Dr. Carl W., School of Life Sciences, U. of Neb., Lincoln, NE. 68588 (Terrestrial pulmonates).
- Gunter, Dr. Gordon, Gulf Coast Research Lab., Ocean Springs, MS. 39564 (Ostreidae).
- Hacker, Ms. Rose, Archbishop Ryan High School, 5616 L. Street, Omaha, NE. 68117 (Freshwater mollusks).
- Hagge, Mrs. Daniel, 20 North Hill Rd., Wausau, WI. 54401.
- Haigh, Ernest S. and Marilyn E. and David, 1940 Stow St., Simi Valley, CA. 93063 (Worldwide seashells; trading and seashell stamps).
- Hall, James J., Environmental Laboratories, Duke Power Company, Rt. 4, Box 531, Huntersville, N.C. 28078 (Asiatic clam, *Corbicula*).
- Hall, Mrs. Warner L., 727 Queen's Rd., Charlotte, NC. 28207 (Self-collected, marine).
- Hamilton, Dr. Paul V., Dept. of Biology, Univ. of W. Florida, Pensacola, FL. 32504 (Behavior and ecology of gastropods).
- Hamilton, Ms. Suzanne, 631 Blossom, Rockville, MD. 20850 (Freshwater gastropods).
- Hamilton, William E., 13568 Magnolia Ave., Corona, CA. 91720 (Pacific Coast, N.A., esp. Southern Calif. to a depth of 110 ft. (Scuba). Favorite areas of study being islands (Catalina, etc.)).
- Hamilton, Mrs. William J. Jr., 615 Highland Rd., Ithaca, NY. 14850.
- Hand, Dr. Cadet H., Bodega Marine Lab, P.O. Box 247 Bodega Bay, CA. 94923.
- Hanley, John H., Branch of Paleontology and Stratigraphy Branch, U.S. Geological Survey, Mail Stop 919, Box 25046, Denver Federal Center, Denver, CO. 80225 (Taxonomy, paleoecology, biostratigraphy, and evolution of Mesozoic and Cenozoic nonmarine Mollusca).
- Hanley, Robert W., Dept. of Biology, Univ. of Alabama, Box 1927, University, AL. 35486 (Physiological ecology, zoogeography and systematics of freshwater mollusks).
- Hanlon, Dr. Roger T., UTMB-MBI, League Hall, R2, 200 University Blvd., Galveston, TX. 77550 (*Cephalopod* culture and behavior).
- Harasewych, M.G., 4938 S. Tupelo Turn, Wilmington, DE. 19808.
- Hargreave, Dr. David, 1104 Berkshire Drive, Kalamazoo, MI. 49007 (Collecting and photography).
- Harman, Dr. Willard N., Biology, State Univ. College at Oneonta, Oneonta, NY. 13820 (Fresh water mollusca).
- Harris, Ms. Bessie B.K., Rt. 8, Box 3, Lake City, FL. 32055.
- Harris, Mr. & Mrs. E. Milton, 3237 Carlisle Rd., Birmingham, AL. 35213.
- Harry, Drs. Harold W. and Mildred, 4612 Evergreen St., Bellaire, TX. 77401.
- Hartenstine, Raymond H., Apt. 722, Grad Village, URI, Kingston, R.I. 02881 (Fresh water malacology).
- Hartman, Joseph H., Dept. Geology/Geophysics, Univ. of Minn., Twin Cities, 108 Pillsbury Hall, Minneapolis, MN. 55455 (Cretaceous-Eocene freshwater mollusks from the Western United States with a special interest in the family Viviparidae).
- Haven, Dr. Dexter S., 336 Lafayette Rd., Yorktown, VA. 23690 (*Mercenaria mercenaria*, *Mya arenaria*, *Crasostrea virginica*).
- Havlik, Mrs. Marian E., 1603 Mississippi St., LaCrosse, WI. 54601 (Naiads of Miss. River).
- Hay, William R., Rt. 6, Bald Hill Road, Jefferson City, MO. 65101 (Land snails, distribution and variation).
- Hazin, Hissa Mussa, Av. Bernardo Vieira de Melo, 3470 Piedade, Jaboatao, Pernambuco, 54.000 Brazil (Basilian marine and foreign marine, conchological books).
- Heath, David J., 595 Court Rd., Onalaska, WI. 54650 (Naiad mollusks of the Mississippi River and tributaries).
- Helms, Don R., RR#3, Box 63, Bellevue, IO. 52031 (Special interest in Mississippi River).
- Hepler, Neil M. and Laura E., 435 S. Federal Highway, Deerfield Beach, FL. 33441 (*Nautilus* and other Cephalopods).
- Herly, Paul W. and Margaret, RD#1, Box 224, Swanton, N.J. 08210 (Paul, fossils; Peg, *Cypraea*).
- Hess, Steven C., RSMAS/BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Cephalopod biology and systematics).
- Hesterman, Caryl A., Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (North American Unionacea).
- Hettick, Mrs. G. Riley, 933 Lynnwood Dr., Bartlesville, OK. 74003.
- Hickey, Ms. Mary T., 4415 Independence St., Rockville, MD. 20853 (Scallops).
- Hickman, Dr. Carole S., Dept. of Palentology, Univ. of Calif., Berkeley, CA. 94720 (Tertiary molluscan paleontology).

- Hickman, Mrs. Harriette L., 20 Wilkie Blvd., Beesley's Point, Marmora, NJ. 08223 (Worldwide *Epitonium*).
- Hickok, George H., 27 Whitney Circle, Windsor, CT. 06095 (Amateur collector).
- Hicks, Mr. and Mrs. Edwin S., 1522 Palmwood Dr., Eau Gallie, FL. 32935 (Recent and fossil marine shells of Western Atlantic).
- Higbee, Ms. Florence and Dr. Joan F. Higbee, 13 North Bedford St., Arlington, VA. 22201.
- Hillman, Robert D. Ph.D., Battelle-Clapp Laboratories, P.O. Drawer AH, Duxbury, MA. 02332 (Molluscan ecology and physiology).
- Hixon, Raymond F., UTMB-MBI, League Hall, R2, Galveston, TX. 77550 (Cephalopods).
- Hoagland, Dr. K. Elaine, Dept. of Biology, Lehigh Univ., Bethlehem, PA. 18015.
- Hoeh, Randy, Museum of Zoology, Univ. of Michigan, Ann Arbor, MI. 48109 (Unionidae).
- Hoggarth, Michael A. and Karen L., 1143 Plumway Dr., Columbus, OH. 43228 (Naiad systematics).
- Hohman, Betty Jean, 10 Ferns, Apt. 101, Highland Park, MI. 48203 (Cones, volutes, muricea).
- Hoke, Mr. Ellet, 3000 University Ave., #63, West Des Moines, IO. 50265 (Distribution of freshwater mussels in Nebraska and the upper Missouri River basin).
- Holiman, Mr. and Mrs. Wayne (Audrey), Box 246, Edinburg, TX. 78539.
- Holle, Dr. Paul A., Ph.D., 131 Holman St., Shrewsbury MA. 01545 (Salt marsh snails).
- Hollister, S.C., 5 Parkway Place, Ithaca, NY. 14850.
- Homan, Mrs. Jacqueline A., N. Halpin Rd., Rt. 5, Box 230, Harlingen, TX. 78550.
- Hopkins, Dr. Sewell H., Rt. 3, Box 232, Gloucester, VA. 23061.
- Horan, Robert C., 352 20th St., Brooklyn, NY. 11215 (Biochemistry of shell formation).
- Hom, Karen J., Univ. of North Carolina Inst. of Marine Sciences, 3407 Arendell St., Morehead City, N.C. 28557 (Freshwater mollusks).
- Hornbach, Daniel, J., Dept. of Biology, Gilmer Hall, Univ. of Virginia, Charlottesville, VA. 22901 (Sphaeriid bivalves).
- Houbrick, Dr. Richard S., Dept. of Invert. Zoology, USNM - Smithsonian, NHB, E 518, Washington, D.C. 20560 (Zoogeography, systematics, evolution).
- Houp, Katy and Ronald E., 519 N. Lexington Ave., Wilmore, KY. 40390 (Freshwater pelecypods).
- Howard, Natalee, 1814 1st Street, Seabrook, TX. 77586 (All shells).
- Hubbard, Mrs. Marian S., 3957 Marlow Court, Seaford, NY. 11783 (Littorinidae; also all juvenile mollusks).
- Hudson, Jim and Barbara, 10702 Cypresswood, Houston, TX. 77070 (Jim, *Cypraea*; Barbara, worldwide).
- Huehner, Dr. Martin K., Dept. of Biology, Hiram College, Hiram, OH. 44234 (Mollusk parasites, freshwater bivalves, esp. Unionidae; ecology of Unionids).
- Hubricht, Leslie, 4026 35th St., Meridian, MS. 39301 (Land snails and Hydrobiidae of Eastern United States).
- Hucks, Claudia M., 8120 Greenridge Rd., North Charleston, S.C. 29405 (East Coast marine, miniatures, microshells).
- Huie, Ms. June, 222 Finland, Grand Prairie, TX. 75050 (All mollusks).
- Hulswit, Mart and Maria, 680 West End Ave., New York, N.Y. 10025 (Scuba).
- Imlay, Dr. Marc J., Box 311, R 12, Columbia, MO. 65201.
- Isom, Billy G., Rt. 3, Box 444, Killen, AL. 35645.
- James, Mrs. Frederic, 850 West 52nd St., Kansas City, MO. 64112.
- James, Matthew J., Dept. of Paleontology, Univ. of California, Berkeley, CA. 94720 (Functional morphology, biogeography, and evolution of mollusks).
- Jass, Joan, 1171 N. 44 St., Milwaukee, WI. 53208.
- Jenkinson, John J. and Carolyn S., 909 Eagle Bend Rd., Clinton, TN. 37716 (Naiades).
- Jennewein, Mr. and Mrs. Paul R., Box 394, Wrightsville, Beach, NC. 28480 (Raises mollusks in aquaria; writes and illustrates articles on shell collecting).
- Joffe, Ms. Anne, 1163 Kittiwake Circle, Sanibel Is., FL. 33957.
- Johns, Veronica Parker, c/o Seashells Unlimited, Inc., 590 Third Ave., New York, NY. 10016.
- Johnson, Barbara Lee, 1615 Yew Street, Mississauga, Ontario, Canada L5H 2C1 (Beginner; favorites cowries and *Murex*).
- Johnson (Way), Elizabeth, Box 83, Topsail, C.B.S., Newfoundland, Canada A0A 3Y0 (Cephalopod blood cells/hemodiosis).
- Johnson, Johnnie, 1635 Oceana Dr., Merritt Island, FL. 32952 (Curator, natural sciences, Brevard Museum, Inc.).
- Johnson, Mrs. Kenneth L., (Charlotte) 3206 Sussex Rd., Raleigh, NC. 27607 (World marine).
- Johnson, Richard I., 124 Chestnut Hill Rd., Chestnut Hill, MA. 02167 (Books).
- Johnstone, Mrs. Adelaide B., 226 Wasp, Corpus Christi, TX. 78412.
- Johnstone, Mrs. Kathleen Yerger, 2209 River Forest Rd., Mobile, AL. 36605.
- Jokinen, Eileen, c/o Peter Rich, U-42, Biological Sciences Group, Univ. of Connecticut, Storrs, CT. 06268 (Freshwater gastropods).
- Jones, Margaret G. and Archie L., 4370 S.W. 14 St., Miami, FL. 33134 (*Liguus*: the Florida tree snail).
- Jones, Meredith L., Invertebrate Zoology, USNM, Smithsonian Institution, Washington, D.C. 20560.
- Jones, Richard H., 1432 Dorsh Rd., South Euclid, OH. 44121.
- Kasson, Bill and Susan M., OSU Museum of Zoology, 1813 N. High St., Columbus, OH. 43210 (Distribution, diversity and systematics).
- Kat, Pieter W., Dept. Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD. 21218 (Unionidae).
- Kay, Dr. E. Alison, Dept. of Zoology, Univ. of Hawaii, 2538 The Mall, Honolulu, HI. 96822 (Indo-Pacific marine mollusca: systematics, ecology, biogeography).
- Keeler, Dr. James H., 4011 Birch Haven, Kingwood, TX. 77339 (Marine, esp. micro gastropods — Epitoniidae and Terebridae).
- Keen, Dr. A. Myra, 2241 Hanover St., Palo Alto, CA. 94306.
- Keferl, Dr. Eugene P., Div. of Nat. Sciences, Brunswick Junior College, Brunswick, GA. 31523 (Terrestrial gastropods).
- Kellogg, Michael G. and Linda Lee, Moss Landing Marine Laboratories, P.O. Box 223, Moss Landing, CA. 95039.
- Kempe, Mrs. HESSIE, 11854 Josse Dr., St. Louis, MO. 63128.
- Kenk, Dr. Vida, 18596 Paseo Pueblo, Saratoga, CA. 95070.
- Kennish, Michael J., Jersey Central Power and Light Co., Madison Ave. at Punch Bowl Rd., Morristown, N.J. 07960 (Shell microstructure in mollusks).
- Kier, William M., Dept. of Zoology, Duke University, Durham, N.C. 27706 (*Cephalopod* functional morphology).
- Kinsey, Bernard, 350 W. 71st, New York, N.Y. 10023 (Land shells: also worldwide marine shells).
- Kitchel, H.E., 113 Cheatham, VPI and SU, Blacksburg, VA. 24060 (Fresh water mollusks, esp. freshwater mussels).
- Kline, Mrs. George F., 240 Makee Rd., Apt. 10-A, Honolulu, HI. 96815.
- Koelsch, Kip W., 26 Oakwood Rd., Leonardo, N.J. 07737 (*Cypraea*, *Cassis* and Atlantic *Nassarius*).
- Kohn, Dr. Alan J., Dept. Zoology, Univ. of Washington, Seattle, WA. 98195.
- Kokai, Frank and Carol, 6960 Tanya Terrace, Reynoldsburg, OH. 43068.
- Kondo, Dr. Yoshio, 809 A. Isenberg St., Honolulu, HI. 96826.
- Kool, Silvard, Media Center, Coastal Carolina College, Conway, S.C. 29526 (Marine/mollusks and freshwater mollusks of Eastern U.S. only).
- Kotrla, M. Bowie, Dept. of Biological Science, Florida State Univ., Tallahassee, FL. 32306 (Parasites of snails).
- Kraemer, Dr. Louise Russert, Dept. of Zoology, Univ. of Arkansas, Fayetteville, AR. 72701 (Freshwater lamellibranchs).
- Kraeuter, Dr. John N., Virginia Institute of Marine Science, Wachapreague, VA. 23480 (Ecology, distribution and systematics of Scaphopoda; ecology and distribution of benthic infaunal communities of the U.S. East Coast).
- Krauss, N.L.H., 2437 Parker Place, Honolulu, HI 96822 (Carnivorous land snails; biology).
- Krull, Pete, 7128 Natalie Blvd., Northfield, OH 44067.

- Kuczynski, Mrs. Florence, 5562 2nd Ave. N., St. Petersburg, FL. 33710 (Collect, exchange, photograph all shells).
- Kurz, Richard M., 1575 N. 118 St. Wauwatosa, WI. 53226 (Large specimen shells).
- Kuzirian, Dr. Alan M., Laboratory of Biophysics, NINCDS, Nat. Inst. of Health, Dept. of Health, Education, and Welfare at the Marine Biological Lab., Woods Hole, MA. 02543 (Nudibranch biology, systematics and taxonomy—phylogeny and morphology).
- Laavy, Thomas L., Rt. 12, Maruca Dr., Greenville, SC. 29609.
- Lamadrid, Yara L., Marine Biomedical Institute H 63, 200 University, Galveston, TX. 77550 (Cephalopods—culturing and physiology (behavioral)).
- Landye, James Jerry, 3465 N. Jamison, Flagstaff, AZ. 86001.
- Lane, Dr. Roger L., Ashabula Campus, Kent State Univ., Ashtabula, OH. 44004 (Morphology, Histology).
- Lange, W. Harry, Dept. of Entomology, Univ. of California, Davis, CA. 95616.
- LaRochelle, Peter B., Dept. of Environmental, Population and Organismic Biology, Univ. of Colorado, Boulder, CO. 80309 (Land molluscs of Colorado, particularly Pupillidae).
- Laursen, Dr. Dan, 4901 East Eastland, Tucson, AZ. 85711 (Arctic, subarctic mollusks; free living larvae of Caribbean and Gulf areas).
- Lee, Dr. Harry G., 709 Lomax St., Jacksonville, FL. 32204 (American mollusks; marine mollusks of the Indian Ocean).
- Leffert, Joseph S., 4000 NE 169 St., #506, North Miami Beach, FL. 33160.
- Lemire, Ross, 184 Grandview Ave., Thornhill, Ont., Canada L3T 1J1.
- Leonard, Dr. A. Byron, 562 Snow Hall, Univ. of Kansas, Lawrence, KS. 66045 (Late Cenozoic mollusca).
- Lerner, Martin, 64 Thompson Ave., Oceanside, NY. 11572 (Worldwide marine).
- Leslie, Dr. F. John, Dept. Biological Sciences, Stanford Univ., Stanford, CA. 94305 (*Haliotis*).
- Levy, Mrs. Esther W., 21 Lee Road, Sharon, MA. 02067.
- Lewis, Harold, 104 S. Twentieth St., Philadelphia, PA. 19103.
- Lewis, Mrs. J. Kenneth (Olive), 3340 Windmill Village #185-0, Punta Gorda, FL. 33950.
- Lewis, Dr. and Mrs. John R., 23 W. 551 Warrenville Rd., Lisle, IL. 60532.
- Lewis, Randall B., 210 Chandler Dr., Mundelein, IL. 60060.
- Lewis, Ronald G. and Susan J., 2524 Garden Court, Bethlehem, PA. 18017 (Marine Gastropoda, particularly Cypraeidae).
- Lillico, Stuart, 4300 Waiialae Ave., B-1205, Honolulu, HI. 96816 (General).
- Lindberg, David R., Applied Sciences, Univ. of California, Santa Cruz, CA. 95064.
- Link, Ms. Christine and Ms. Dee, 1 Blue Bell Circle, Lafayette, LA. 70507.
- Linsley, Dr. Robert M., 111 East Lake Rd., Hamilton, N.Y. 13346 (Paleozoic Gastropoda).
- Lipford, Michael L., 2017 Airline Blvd., Portsmouth, VA. 23701 (Freshwater mussels).
- Littleton, Thomas G., Bureau of Economic Geology, Box X, University Station, Austin, TX. 78712.
- Logan, Robert W., 145 Northwood, Frankfort, KY. 40601 (Freshwater mussels and snails).
- Long, Dr. Glenn A., 409 Sheridan Circle, Charlestown, W.VA. 25314 (Ethnoconchology).
- Lopinot, A.C., 45 Northcrest, Litchfield, IL. 62056 (Aquatic biologist, taxonomy and life history of freshwater mussels).
- Lowry, Walter G., 552 Old Lundy Rd., Macon, GA. 31210 (Western Atlantic).
- Lubinsky, Dr. Irene, 32 Thatcher Drive, Winnipeg, Man., Canada R3T 2L2 (Marine bivalves of the Canadian Arctic).
- Lupold, Hugh M. and Linda S., Box 396, Holly Hill, S.C. 29059 (S.C. Coasts and Sanibel, FL.).
- Lustgarten, Linda, 44 Righters Mill Road, Gladwyn, PA. 19035 (Bahamas).
- Lyons, William G. and Carol B., 4227 Porpoise Dr. SE, St. Petersburg, FL. 33705 (Marine).
- MacBride, Grace R., 143 Hartman Rd., North Wales, PA. 19454.
- MacKenzie, Roger Anthony, Lot 12, Mor ne Coco Rd., Westmoorings, Trinidad, West Indies (Strombidae).
- Mackie, Dr. Gerry L., Dept. of Zoology, Univ. of Guelph, Guelph, Ont. Canada N1G 2W1 (Freshwater mollusca).
- MacMillan, Gordon K., 169 Glenfield Dr., Pittsburgh, PA. 15235.
- Macy, William K. III, 146 Main St., North Kingstown, R.I. 02852 (Cephalopods).
- Maes, Virginia Orr, Dept. of Mollusks, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103.
- Magee, Mrs. Virginia L., Life Science Dept., Mitchell College, New London, CT. 06382 (New England mollusks, both living and Pleistocene).
- Malek, Dr. Emile, Tulane Univ. Medical School, 1430 Tulane Ave., New Orleans, LA. 70112 (Parasitology).
- Malone, Elsie, 2422 Periwinkly Way, P.O. Box 54, Sanibel Is., FL. 33957 (Elsie Malone Specimen Shells—buy, sell, exchange worldwide).
- Mann, Julia, Data Research Associates, 257 Park Ave. South, New York, N.Y. 10010.
- Marshall, Elsie J., 2237 N.E. 175th St., Seattle, WA. 98155 (World shells; exch.).
- Marti, Mrs. Ann P., P.O. Box 7, Trinity, AL. 35673 (Panamic marine shells and worldwide *Murex*).
- Martins, Antonio M., Frias, Dept. of Zoology, Univ. of Rhode Island, Kingston, RI. 02881.
- Mather, Dr. Charles M., University of Science and Arts of Oklahoma, Box 3457, Chickasha, OK. 73018 (Systematics and ecology of terrestrial molluscs and freshwater mussels).
- Mathiak, Harold A., 209 S. Finch St., Horicon, WI. 53032 (Natural history of Wisconsin clams and recent species distribution; effects of fish toxicants on clams).
- May, Miss L. Helen, 8110 Ketcham Rd., South, Bloomington, IND. 47401 (N.A. seashells, emphasis on continental U.S.A.).
- Mayers, Dan, 648 Wiltshire Dr., State College, PA. 16801 (Taxonomy and life histories of mollusks).
- Mazurkiewicz, Dr. Michael, Dept. of Biological Sciences, Univ. of Southern Maine, Portland, ME. 04103 (Larval development and ecology of estuarine mollusks).
- McCaleb, John E., Rt. 1, Brilliant, AL. 35548 (Freshwater mollusks of N.A., esp. Pleuroceridae).
- McCallum, John and Gladys, 4960 Gulf of Mexico Dr., Apt. PH6, Longboat Key, FL. 33548.
- McCarty, Col. William A., 424 Hunting Lodge Dr., Miami Springs, FL. 33166.
- McCrary, Dr. Anne B., 411 Summer Rest Rd., Wilmington, NC. 28403.
- McGeachin, Dr. William T., 2246 Rutherford Wynd, Louisville, KY. 40205 (Trematode host-parasite relationships, behavior, ecology).
- McGee, Paul L. and Helen, 10211 Bessemer, Houston, TX. 77034.
- McGhee, Mrs. Sandra L., 8401 W. Sample Road, #14, Coral Springs, FL. 33065 (Research on Patellidae, Acmaeidae and Lepetidae).
- McGinty, Thomas L., Box 765, Boynton Beach, FL. 33435.
- McHugh, Mrs. John (Ellen), 4654 Quarry Ridge Tr., Rockford, IL. 61103 (*Murex*).
- McInnes, Mrs. Cornelia G., F-6 Raleigh Apts., Raleigh, NC. 27605 (All marine mollusks).
- McLean, Dr. James H., Los Angeles County Museum, 900 Exposition Blvd., Los Angeles, CA. 90007.
- McLeod, Dr. Michael J., Biology Dept., Belmont Abbey College, Belmont, NC. 28012 (Systematics and evolution).
- McRae, Mrs. Catherine, 1984 Roseate Lane, Sanibel Is., FL. 33957.
- Mead, Albert R., Associate Dean, Liberal Arts College, 347 Modern Languages Bldg., Univ. of Arizona, Tucson, AZ. 85721.
- Menzel, Dr. R.W., Dept. Oceanography, Florida State Univ., Tallahassee, FL. 32306 (Marine clams and oysters, biology).
- Merrill, Arthur and Hamet, 74 High Street, Bath, ME. 04530.
- Metcalf, Dr. Artie L., Dept. of Biological Sciences, Univ. of Texas at El Paso, El Paso, TX. 79968 (Terrestrial Gastropoda of S.W. U.S.).
- Metz, George, 121 Wild Horse Valley Drive, Novato, CA. 94947 (Chitons).
- Meyer, Harvey G., P.O. Box 61, Captiva, FL. 33924.

- Michaelson, Eliot, The Shell Gallery, Piccadilly Sq., 77 Union St., Newton Centre, MA. 02159.
- Michelson, Dr. Edward H., 44 Bishop Drive, Framingham, MA. 01701 (Medical malacology).
- Mikkelsen, Paul and Paula, Harbor Branch Foundation, RFD 1, Box 196, Ft. Pierce, FL. 33450 (Paul—Donacidae; Paula—Tellinidae, Littorinidae).
- Miles, Dr. Charles D., Dept. of Biology, Univ. of Missouri—Kansas City, Kansas City, MO. 64110.
- Miller, Barry B., Dept. of Geology, Kent State Univ., Kent, OH. 44242 (Non-marine Pleistocene, malacology).
- Miller, Dr. Walter B., 6140 Cerrada El Ocote, Tucson, AZ. 85718.
- Miser, Wendel L., 8404 Crowley Place, Alexandria, VA. 22308 (Fresh water mollusks).
- Moore, Mrs. Donald R. (Cynthia), MAC, RSMAS, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Moore, Dr. Donald R., RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149.
- Moore, Eric and Eileen, P.O. Box 6606, Orange, CA. 92667 (General).
- Morrill, J.B., Division of Natural Sciences, New College, Univ. of South Florida at Sarasota, 5700 N. Tamiami Trail, Sarasota, FL. 33580 (Gastropod embryology).
- Morrison, Dr. J.P.E., 1330 4th St. S.W., Washington, D.C. 20024.
- Morrison, Robert W., P.O. Box 15011, Sarasota, FL. 33579 (Marine shells, esp. *Cypraea*, *Voluta*, *Oliva* and *Murex*).
- Morse, Dr. M. Patricia, Marine Science Institute, Northeastern University, Nahant, MA. 01908 (Interstitial molluscs (opisthobranchs and solengasters) Opisthobranchia).
- Mousley, Louis B., 35350 Panorama Dr., Yucaipa, CA. 92399 (Mousley Museum of Natural History).
- Mulvey, Margaret, Dept. of Zoology, Rutgers Univ., Busch Campus, Piscataway, N.J. 08854 (Population biology; host-parasite relationships).
- Murray, Mrs. Francis A., 3741 N.E. 24th Ave., Lighthouse Point, FL. 33064.
- Murray, Dr. Harold D., Biology Dept., Trinity Univ., San Antonio, TX. 78284 (Unionidae; distribution and parasites).
- Myer, Dr. Donal G., Dept. of Biological Science, Southern Illinois Univ. at Edwardsville, IL. 62025 (Land snails).
- Naide, Dr. Meyer, 2034 Spruce St., Philadelphia, PA. 19103.
- Neck, Dr. Raymond W., Texas Parks and Wildlife Dept., 4200 Smith School Rd., Austin, TX. 78744 (Ecology, evolution and biogeography of nonmarine mollusca).
- Nelson, David A., 308 Overlook, Vicksburg, MS. 39180.
- Neville, Bruce D., 8221 SW 72 Ave., Apt. #377, Miami, FL. 33143 (Mangrove mollusks/systematics and ecology).
- Newman, Ms. Leslie J., Dept. of Zoology, Univ. of Guelph, Ontario, Canada N1G 2W1 (Pteropods (Opisthobranchia-Gastropoda), general marine mollusc ecology).
- Nicol, Dr. David, P.O. Box 14376, University Station, Gainesville, FL. 32604.
- Nieburger, Edward and Gayle, P.O. Box #95, Shawsheen Station, Andover, MA. 01810 (Marine shells of Florida and Massachusetts; shell books).
- Nilson, Joy S., Rt. 5, Box 3156, Bonita Springs, FL. 33923 (New England mollusks, Florida shells).
- Nimeskern, Phillip W., Jr., 38 Minihan's Lane, Quincy, MA. 02169 (Nudibranchia; functional morphology and feeding).
- Norman, Helen D., RFD #1, Box 222, 3 Ludlow Lane, Palisades, N.Y. 10964.
- Noseworthy, Ronald G., P.O. Box 104, 41 Main St., Grand Bank, Newfoundland, Canada AOE 1W0 (North Am. circumboreal mollusks; also Clausiliidae and Turridae).
- Notter, Miss Hellen, 1115 S. Edgewood Ave., Apt. 608, Jacksonville, FL. 32205.
- Nunley, Rodney E., 4800 Ft. Crockett Blvd., #E3, Galveston, TX. 77550 (Ecology and distribution of tropical and subtropical marine mollusks).
- Nunnally, Mrs. Sally and Douglas G., 512 N. Channel Drive, Apt. B., Wrightsville Beach, N.C. 28480 (Self-collected marine).
- Nybakken, Dr. James, Moss Landing Marine Laboratories, Box 223, Moss Landing, CA. 95039.
- Odé, Dr. Helmer, 4811 Braeburn Drive, Bellaire, TX. 77401 (Gulf of Mexico marine).
- Oesch, D. Ronald, 9 Hill Dr., Glendale, MO. 63122 (Missouri mussel zoogeography).
- Oetzell, Miss Edith M., 518 S. Ardmore Ave., Villa Park, IL. 60181 (*Conus*).
- Old, William E. Jr., Dept. of Mollusks, American Museum of Natural History, Central Park W. at 79th St., New York, NY. 10024.
- Oliveira, Dr. Maury Pinto, Dept. Biologia-Malacologia, Universidade Federal, DeJuiz De Flora, Cidade Universitaria, 36100 Juiz de Fora, Minas Gerais, Brazil.
- Olivera, Dr. Baldomero M., Dept. of Biology, Univ. of Utah, Salt Lake City, Utah 84112 (*Conus* toxins; Philippine marine mollusks).
- Orchard, C.D., P.O. Box 115, McQueeney, TX. 78123.
- Ostheimer, Alfred J., III, 1030 Mansion Ridge Road, Santa Fe, N.M. 87501.
- Otway, Thomas, 34 Livingston, St., Apt. 4, Brooklyn, N.Y. 11201 (Systematics).
- Pagel, Robert and Lorene, 5 South Grand Ave., Deerfield, WI. 53531 (Culture—intensive, extensive).
- Palmer, Dr. Katherine V.W., 206 Oak Hill Rd., Ithaca, NY. 14850.
- Parker, James Larry, 8705 Valleybrook Rd., Birmingham, AL. 35206 (Caribbean mollusks).
- Parker, Robert S., Freeport Minerals Rand D. Lab, Box 26, Belle Chasse, LA. 70037.
- Parmalee, Dr. Paul W., Prof. of Zooarchaeology, Dept. of Anthropology, Univ. of Tenn., Knoxville, TN. 37916 (Freshwater mollusks from archaeological sites).
- Parodiz, Dr. Juan Jose, 409 Ruthwood Ave., Pittsburgh, PA. 15227 (Neotropical mollusks and fresh water gastropods of U.S.A.).
- Pearce, Timothy A., 4104 Gull Harbor Road NE, Olympia, WA. 98506 (Ecology and distribution of land mollusks of the Pacific Northwest).
- Pena Monardez, Renan D., Av. Argentina 252, Dpto. 11, Antofagasto, Chile (Taxonomy, morphology and land snails).
- Penchaszadeh, Dr. Pablo E. and Genevieve de Mahieu de Penchaszadeh, INTECMAR, Universidad Simon Bolivar, Caracas, Venezuela (Apartado Postal 80.659 (Pablo, biogeography and taxonomy; Genevieve, biologist, Dept. de Biologia de Organismos, Univ. Simon Bolivar APDO 80659).
- Perron, Frank E., Pacific Biomedical Research Center, 41 Ahui St., Honolulu, HI. 96813 (Reproductive ecology of marine gastropods (*Conus*)).
- Petit, Mr. and Mrs. Richard, P.O. Box 30, North Myrtle Beach, SC. 29582 (World shells).
- Petranka, John G., Dept. of Biology, 101 Morgan Bldg., Univ. of Kentucky, Lexington, KY. 40506 (Ecology and systematics of terrestrial gastropods).
- Petuch, Dr. Edward Jr., Dept. of Zoology, Univ. of Maryland, College Park, MD. 20742 (Zoogeographer).
- Pierce, Dr. Harold G., P.O. Box 916, O'Neill, NE. 68763.
- Piplani, Shirley A., 26 Jameson Place, West Caldwell, NJ. 07006 (Chitons).
- Pondick, Jeffrey S., Life Sciences U-43, Univ. of Connecticut, Storrs, CT. 06268 (Studies the effects of parasites on marine mollusks).
- Porter, Hugh J., UNC Inst. Marine Sciences, Morehead City, NC. 28557 (Systematics, culture of bivalves).
- Post, Mrs. Alfred P. Jr., P.O. Box 65, Darlington, MD. 21034.

- Powell, Dr. Eric N., Dept. of Oceanography, Texas A&M University, College Station, TX. 77840 (Pyramidellidae; benthic ecology).
- Pratt, W.L. Jr. and Suzann Denton Pratt, Museum of Natural History, Univ. of Nevada, Las Vegas, 4505 Maryland Pkwy. S., Las Vegas, NV. 89154.
- Prezant, Robert S., Dept. of Biology, Univ. of Southern Mississippi, Southern Station, Box 5018, Hattiesburg, MS. 39401 (Anomalodesmata; mantle structure and function/evolution).
- Proctor, Grosvenor, Box 546, Quanset Road, South Orleans, MA. 02662 (East and Gulf coasts of USA and islands of Hawaii).
- Pulley, Dr. Thomas E., Director Emeritus and Manager of Collections, Houston Museum of Natural Science, P.O. Box 8175, Houston, TX. 77004.
- Quigley, (Mrs.) Jacqueline Stocksdales, 3502 North 93rd St., Omaha, NE. 68134 (Cypraeidae and related species; also the use of shells in other civilizations; fossil shells).
- Quinn, James F. Jr., Marine Research Laboratory, 100 Eighth Ave. S.E., St. Petersburg, FL. 33701 (Trochidae and Turridae).
- Quintero, Richardo, Calle 58 #32-91 Bucaramanga (Santander), Colombia (Marine molluscs of the Caribbean Region).
- Raeihle, Dorothy and George, 211 Milligan Rd., West Babylon, NY. 11704.
- Rathjen, Dr. Warren F., National Marine Fisheries Service, X1109, Gloucester, MA. 01930 (Cephalopods).
- Raymond, Torrance, C., 99 Ridgeview Rd., Poughkeepsie, NY. 12603.
- Reader, Mr. and Mrs. William R. (Esther F.), 4772 49th Ave. North, St. Petersburg, FL. 33714 (Live mollusks).
- Reeder, Dr. Richard L., Faculty of Nat. Sci., Univ. of Tulsa, Tulsa, OK. 74104 (Land pulmonates).
- Reese, David S., 11 Brook Bridge Rd., Great Neck, N.Y. 11021 (Shells in archeology; circum-Mediterranean marine invertebrates; fresh water shells and land snails).
- Rehder, Dr. Harald A., 5620 Ogden Rd., Washington, D.C. 20016.
- Rice, Thomas C., P.O. Box 33, Port Gamble, WA. 98364.
- Richards, Charles S., Biomedical Research Institute, 12111 Parklawn Drive, Rockville, MD. 20852 (Freshwater mollusks, host-parasite relations, mollusks, pathology and genetics).
- Rios, Dr. Eliezer de C., Box 379, Museo Oceanografico, Rio Grande, RS. 96200, Brazil.
- Ritchie, Mrs. Robert M., 17 Country Club Pl., Bloomington, IL. 61701.
- Roach, Frank, 1028 Belvoir Rd., Norristown, PA. 19401 (Specializing in *Cardium*, *Chama* and *Pecten*).
- Robbins, Beth S., 415 Penn Road, Wynnewood, PA. 19096 (Bahamas).
- Roberts, Mr. and Mrs. H. Wallace, Hopkinson House, Apt. 2816, Washington Square South, Philadelphia, PA. 19106 (Marine).
- Robertson, Dr. Robert, Dept. of Malacology, Academy of Natural Sciences, 19th and the Parkway, Philadelphia, PA. 19103 (Marine).
- Rollins, Dr. Harold B., Dept. of Geology, Univ. of Pittsburg, Pittsburg, PA. 15260 (Paleozoic Archaeogastropoda, Monoplacophora-systematics, Paleocology).
- Romberger, Penroe H., 615 Wayne Dr., Mechanicsburg, PA. 17055 (Conidae and Cypraeidae).
- Root, John, P.O. Box 182, West Palm Beach, FL. 33402.
- Roper, Dr. Clyde F.E. and Ingrid, Dept. of Invertebrate Zoology, USNM - Smithsonian, Washington, D.C. 20560 (Systematics and ecology of the Cephalopoda).
- Ropes, John W., 21 Pattee Rd., East Falmouth, MA. 02536.
- Rosen, Thomas S., 104 Cabro Court, Novato, CA. 94947 (Cones and cowries).
- Rosenberg, Gary, 27 South Hinchman Ave., Haddonfield, N.J. 08033 (Marine gastropods, esp. Turridae and Mitridae; South American Tertiary fossils).
- Rosewater, Dr. and Mrs. Joseph, Room E - 512, Dept. Invert. Zoology (Mollusks), USNM, Smithsonian, Washington, D.C. 20560.
- Roth, Barry, Dept. of Invert. Zoology, Calif. Academy of Sciences, San Francisco, CA. 94118.
- Rotter, Saul D., M.D., 130 Sunrise Ave., Palm Beach, FL. 33480 (Cones, volutes, cowries, olives).
- Roworth, Edwin C., 1361 Windsor Rd., Cardiff-by-the-Sea, CA. 92007 (World shells and sea life).
- Rule, Patricia L., Div. of Marine Fisheries, 18 Heritage Prof. Bldg., Sandwich, MA. 02563.
- Runnels, Randy J., Rt. 2, Box 2576, Brazoria, TX. 77422 (Gulf of Mexico mollusks, esp. gastropods).
- Russell, Charles E., 10602 Jordan Road, Carmel, IN. 46032 (Land; freshwater).
- Russell, Dr. Henry D., 50 Springdale Ave., Dover, MA. 02030.
- Russell, Dr. Lois S., Royal Ontario Museum, 100 Queen's Park, Toronto, Ont., Canada M5S 2C6.
- Russell-Hunter, Dr. W.D., Dept. of Biology, 112 Lyman Hall, Syracuse Univ., Syracuse, N.Y. 13210.
- Sage, Walter E. III, 1123 Hathaway, Louisville, KY. 40215 (All mollusks).
- Sartor, James C., 5606 Duxbury, Houston, TX. 77035 (Microscopic marine mollusks - exchange or purchase).
- Scarabino, Sr. Victor, Instituto de Investigaciones Biologicas, Avda. Italia 3318, Montevideo, Uruguay.
- Schell, Frederic B. Jr., 1200 Peppertree Lane, Apt. 102, Sarasota, FL. 33581 (Nov. 1 to June 1); The Brooklands, Colebrook, CT. 06021 (June 1 to Nov. 1).
- Scheltema, Dr. Amelie H., Woods Hole Oceanographic Institution, Woods Hole, MA. 02543 (Aplacophora).
- Schilling, Mr. and Mrs. Albert E., 419 Linden Ave., Glenside, PA. 19038 (Mr., *Cypraea*; Mrs., *Murex*; both, *Conus*).
- Schilling, Mrs. Frieda (Mrs. Omar), 3707 Lan Dr., St. Louis, MO. 63125.
- Schmidt, John E., P.O. Box 403, Cookeville, TN. 38501 (Mussels of the Cumberland River system).
- Schriner, Miriam W. and Howard Jr., box 1288, LaBelle, FL. 33935 (Paleo-malacological research).
- Seberg, Dr. G. Herbert, Box 787, Hastings, NE. 68901 (All shells).
- Seip, William F., 1555 Stonewood Rd., Baltimore, MD. 21239.
- Serrill, Linda and Richard, P.O. Box 207, Matagorda, TX. 77457 (Shells of the Matagorda Peninsula, TX).
- Shasky, Dr. Donald R., 834 Highland Ave., Redlands, CA. 92373.
- Shimek, Dr. Ronald, Friday Harbor Laboratories, Univ. of Washington, Friday Harbor, WA. 98250 (Turrid gastropods, gastropod systematics, subtidal benthic marine ecology).
- Shoemaker, Alan H., 330 Shareditch Rd., Columbia, SC. 29210 (Marine gastropods).
- Sibley, Frederick D., 196 Christopher St., Montclair, NJ. 07042.
- Sickel, Dr. James B., Biol. Dept. Murray State Univ., Murray, KY. 42071 (Unionidae ecology and physiology).
- Siddall, Scott E., School of Marine Sci. BLR, 4600 Rickenbacker Causeway, Miami, FL. 33149 (Physiological ecology of bivalves, particularly marine mussels and mariculture of mussels).
- Siekman, Mrs. Lula B., 5031 41st St., St. Petersburg, FL. 33711.
- Sigler, Stephen A. and Donell L., Specimen Shells, P.O. Box 14169 B, Orlando, FL. 32857 (Marine shells with an avid interest in *Cypraea*).
- Simon, Dr. Joseph L., Biology Dept., Univ. of South Florida, Tampa, FL. 33620 (Development, ecology).
- Skoglund, Carol, 3846 E. Highland Ave., Phoenix, AZ. 85018 (Panamic Province shells).
- Smith, Douglas G., Dept. of Zoology, Morrill Science Center, Univ. of Mass., Amherst, MA. 01003 (Land and freshwater mollusca of NE North America).
- Smith, Dr. Judith Terry, 1527 Byron St., Palo Alto, CA. 94301.
- Smith, Mrs. Muriel F.I., National Museum of Natural Sciences Mollusc Section, Ottawa, Ont., Canada K1A 0M8.

- Smith, Vivienne B., Rt. #1, Box 753, Bokeelia, FL. 33922.
- Smrček, Dr. Jerry C., 3316 King William Dr., Olney, MD. 20832 (Effects of pollution on freshwater mollusca).
- Snyder, Martin Avery, 745 Newton Rd., Villanova, PA. 19085.
- Sohl, Dr. Norman F., 10629 Marbury Rd., Oakton, VA. 22124.
- Solem, Dr. Alan, Dept. of Zoology, Field Museum of Nat. History, Chicago, IL. 60605.
- Sparks, Richard E., III. Natural History Survey, Box 599, Havana, IL. 62644.
- Sphon, Gale G. Jr., Los Angeles County Museum, Invertebrate Zoology, 900 Exposition Blvd., Los Angeles, CA. 90007.
- Stansbery, Dr. David H., The Ohio State University Museum of Zoology, 1813 North High St., Columbus, OH. 43210 (Naiads).
- Stanzione, Mrs. Antonetta R., 55 Green Ave., Barrington, R.I. 02806 (Shell life importance in the balance of nature).
- Starnes, Lynn B. and Wayne C., TVA Forestry Bldg., Norris, TN. 37828 (Zoogeography of southeastern U.S. mollusks).
- Steger, Mrs. Dan (Barbara), 2711 68th St. N., Tampa, FL. 33619 (Marine fauna, Gulf of Mexico).
- Stein, Dr. Carol B., The Ohio State University Museum of Zoology, 1813 North High St., Columbus, OH. 43210 (Naiads, Gastropoda).
- Stelzig, Theresa (Mrs. O. Cline), 109 Duke Lane, Portland, TX. 78374.
- Stephen, Stephen J., Huntsman Marine Lab, Brandy Cove, St. Andrews, N.B. EOG 2X0, Canada (Cephalopod taxonomy; North Western Atlantic).
- Stephens, Susan B., 425 Lighthouse Way, Sanibel, FL. 33957 (Muricidae and Vasidae, recent and fossil).
- Stern, Dr. Edward M., Dept. of Biology, Univ. of Wisconsin-Stevens Point, Stevens Point, WI. 54481 (Systematics and ecology of terrestrial gastropods and Unionidae).
- Steward, Orville M., P.O. Box 33, Plymouth, Vermont 05056.
- Stingley, Dale V., P.O. Box 113, LaBelle, FL. 33935.
- Strenth, Dr. Ned E., Dept. of Biology, Angelo State Univ., San Angelo, TX. 76901 (General ecology, systematics, and larval development of opisthobranch mollusks of the genus *Aplysia*).
- Stresau, Mary Ann, c/o R. Pilon, 1720 Kingsburg, Dearborn, MI. 48128 (Yacht "Sabot" Panama, Polynrdia, Caribbean).
- Strieder, Denise J., M.D. 143 Laurel Rd., Chestnut Hill, MA. 02167 (American seashells).
- Sutow, Dr. Wataru W., 4371 North MacGregor Way, Houston, TX. 77004 (Strombus; exchange).
- Swift, Dr. Mary L., Dept. of Biochemistry, College of Medicine, Howard University, Washington, D.C. 20059 (Oysters, bivalves; marine-nutrition, intermediary metabolism).
- Tate, Mrs. Mildred, 211 Huisache, Lake Jackson, TX. 77566.
- Taxon, Anne and Albert, 1300 NE 191st. St., North Miami Beach, FL. 33179.
- Taylor, Dr. Jane B., 5803 Accomac St., Springfield, VA. 22150 (Prosobranchs-life histories, nutrition and growth rates, and premetamorphic veligers).
- Taylor, Dr. Dwight W., Tiburon Center for Environmental Studies, P.O. Box 773, Tiburon, CA. 94920.
- Taylor, Myra L., 7602 McCullough Ave., San Antonio, TX. 78216 (Shells of the Texas coast).
- Taylor, Dr. Ralph W., Dept. of Biological Science, Marshall University, Huntington, W.VA. 25701 (Mussels of W.VA. and KY., land snails of W.VA.).
- Teskey, Mrs. Margaret C., P.O. Box 273, Big Pine Key, FL. 33043.
- Theler, James L., 2020 Overlook Pass #7, Middleton, WI. 53562 (Paleoecological interpretation through mollusks).
- Thomas, Dr. Grace, Dept. of Zoology, Univ. of Georgia, Athens, GA. 30602 (Sphaeriids).
- Thomas, Miss Marguerite T., P.O. Box 721, Swansboro, NC 28584.
- Thompson, Dr. Fred G., Florida State Museum, Gainesville, FL. 32611 (Land and freshwater mollusks; systematics).
- Tippett, Dr. and Mrs. Donn L., 10281 Gainsborough Rd., Potomac, MD. 20854 (Western Atlantic, living and fossil - Cones, *Murex*, scallops, Fissurellidae).
- Tirol, Dr. Tristan, c/o Jhun Simoy/Dr. T.G. Tirol, 62nd Avn. Co., APO N.Y. 09039.
- Toll, Ronald B., Rosenstiel School of Marine and Atmospheric Science - BLR, 4600 Rickenbacker Causeway, Virginia Key, FL. 33149 (Systematics of Cephalopoda).
- Tomlinson, Mrs. Marjorie R. and Robert S., 4400 East-West Highway, #833, Bethesda, MD. 20014 (General).
- Tompa, Dr. Alex S., Museum of Zoology, Univ. of Michigan, Ann Arbor, MI. 48109 (Land and freshwater mollusks).
- Treece, D. Granvil, P.O. Box 1718, Kingshill, St. Croix, USVI 00850 (Molluscan systematics; taxonomy; zoogeography).
- Trinidad, Dr. Victor Jose V., 22040 Westhampton, Oak Park, MI. 48237 (Cowries, cones, olives and *Tibia* shells).
- Tripp, Ms. Jay J., 212 Connecting Road, Pittsburgh, PA. 15228 (Worldwide marine and fossils).
- Tunnell, Dr. John W. Jr., Corpus Christi State Univ., Corpus Christi, TX. 78412 (Systematics, distribution and ecology of reef and bank mollusks in Gulf of Mexico).
- Turgeon, Drs. Donna D. and Kenneth W., 9027 Giltinault, Springfield, VA. 22153 (Donna: National Marine Fisheries Service, Fees Regulations Division, 3300 Whitehaven St. NW, Washington, D.C.; Kenneth: Environmental Data Information Service, NMFS, 3300 Whitehaven St. NW, Washington, D.C.).
- Turner, Dr. Ruth D., Mollusk Dept., Museum of Comparative Zoology, Harvard Univ., Cambridge, MA. 02138.
- Underwood, Harold T., Dept. of Biology, Texas A&M University, College Station, TX. 77843 (Interested in molluscs as they serve in the capacity as hosts in parasite life cycles).
- Vagvolgyi, Dr. Joseph, Biology Dept., College of Staten Island, B-204, 715 Ocean Terrace, Staten Island, NY. 10301 (Evolutionary theory; zoogeography).
- Vail, Dr. Virginia, 607-28 Dixie Dr., Tallahassee, FL. 32304.
- Van der Schalie, Dr. Henry, 15000 Buss Rd., Manchester, MI. 48158.
- Van Devender, Amy S., Rt. 4, Box 261-B, Boone, NC. 28607 (Land snails).
- Van Heukelem, Dr. W.F., Horn Point Environmental Laboratories, Univ. of Maryland, P.O. Box 775, Cambridge, MD. 21613 (Growth, bioenergetics, aging, life-history and behavior of Cephalopods).
- Vaughan, William N., 3430 Winter Wood Ct., Marietta, GA. 30062 (Cones, cowries, int. in trading).
- Vecchione, Dr. Michael, P.O. Box 224, McNeese State Univ., Lake Charles, LA. 70609 (Ecology and systematics of pelagic mollusks).
- Vega, Dr. Luis Eduardo, 420 S. Essex Ln., Tucson, AZ. 85711.
- Vercoe, Harold John, Rt. 8, Box 43, Asheboro, N.C. 27203 (Ecology, taxonomy).
- Vidrine, Malcolm F., 313 Davis St., Jennings, LA. 70546 (Fresh water mussels of Louisiana; study of water mites).
- Villarroel, Dr. Maria M., Instituto de Ingenieria, Dept. Ing. Ambiental, APDO 70-472, Mexico 20, DF., Mexico.
- Virji, Ashiraf, P.O. Box 45082, Los Angeles, CA. 90045 (*Cypraea*, cones, volutes).
- Vokes, Dr. Harold E. and Dr. Emily H., Dept. of Geology, Tulane Univ., New Orleans, LA. 70118 (Mesozoic and Tertiary mollusks; fossil and recent Muricidae).
- Voss, Dr. Gilbert L. and Nancy A., Div. of Biology and Living Resources, Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL. 33149 (*Cephalopods*—systematics and life history of pelagic squids).

- Wagner, Robert J.L. and Frances E. RD #1, Box 21, Marathon, FL. 33050.
- Walklet, Gerrie, Randolph Farms, #1401, 13300 Indian Rocks Rd., Largo, FL. 33540.
- Waller, Dr. Thomas R., Dept. of Paleobiology, Smithsonian, Washington, D.C. 20560 (Zoogeography, geology, evolution of Cenozoic Pectinidae).
- Walsh, Lyle, College of Marine Studies, Lewes, DE. 19958 (Calcium transport as related to calcification).
- Walter, L.J., 6349A Columbia Pike, Baileys Crossroads, VA. 22041 (Hobby).
- Warmke, Germaine L., 1711 S.W. 43rd Ave., Gainesville, FL. 32608 (Caribbean mollusks).
- Warren, Dr. Sol L., 375 Garden Blvd., Garden City, N.Y. 11530.
- Wasili, Mrs. John, P.O. Box 187, Frisco, N.C. 27936.
- Waters, Ruth A., 150 Barker Hill Dr., RFD 3, Guilford, CT. 06437 (U.S. marine, principally E. Coast).
- Way, Carl Michael, 279-H SE Lilly Ave., Corvallis, OR. 97330 (Ecology and physiology of the Sphaeriidae and freshwater gastropods).
- Wayne, Dr. William J., M.H. 412, Dept. of Geology, Univ. of Nebraska, Lincoln, NE. 68588 (Pleistocene non-marine mollusks).
- Webb, Dr. Glenn R., Rt. 1, Box 1158, Fleetwood, PA. 19522.
- Webb, John A. and Rhoda, 5031 Redcliff Court, Dunwoody, GA. 30338.
- Weihing, Dr. Robert R., Worcester Foundation for Experimental Biology, 13 Old Brook Road, Shrewsbury, MA. 01545 (Hobby).
- Weingartner, Mathilde P., 17 Amelia Court, Staten Island, N.Y. 10310.
- Weisbord, Norman E. and Nettie S., Dept. of Geology, Florida State Univ., Tallahassee, FL. 32306 (Cenozoic and recent mollusks).
- Weiss, Harold M., 3607 Sarah Dr., Wautagh, NY. 11793 (Conidae and Cypraeidae).
- Welty, Mr. and Mrs. Stephen L., Box 639, Dubois, WY. 82513.
- Werner, Milton, 70 Richmond St., Brooklyn, NY. 11208.
- West, Dr. Ronald R. and L.E. Gundrum, Dept. of Geology, Kansas State Univ., Manhattan, KS. 66506 (Paleozoic bivalve palaeoecology (R.R.); Gastropod functional morphology (Lois)).
- Wheel, Adlai B. Sr., 4501 West Seneca Turnpike, Syracuse, NY. 13215.
- White, Kenneth J., R.Ph., 2587 Ballew Ct., Marietta, GA. 30062 (Caribbean Province shells).
- Whiteside, Mrs. Smith (Jeanne), 10520 S. Tropical Trail, Merritt Island, FL. 32952.
- Williams, Mrs. Edward P. (Linda), Crosstrees Hill Road, Essex, CT. 06426 (Collecting, preserving and protecting mollusks and study of habitats).
- Williams, Dr. James D., 2318 Hiladrose Dr., Silver Spring, MD. 20902 (Freshwater mussels; zoogeography and systematics).
- Williams, Mrs. Thomas G., Rt. 3, Box 28A, Sarasota, FL. 33580 (Caribbean and miniature).
- Williamson, Catherine, Rt. 1, Box 80-D, Riviera, TX. 78379 (Natural history - ecology).
- Willis, Jeffrey A., 402 Kings Highway, Lewes, DE. 19958 (Worldwide, general).
- Wilson, Dr. Druid, Room 501, U.S. National Museum, Washington, D.C. 20560.
- Wilson, John M., 28014 Green Willow, Farmington Hills, MI. 48018.
- Windnagel, John, 3581 Snouffer Rd., Worthington, OH. 43085 (Florida shells).
- Winner, Bea, 342 Southwind Dr. #101, North Palm Beach, FL. 33408 (Gastropod embryology).
- Wolfe, Dr. Douglas A., 68-A Wild Horse Circle, Pine Brook Hills, Boulder, CO. 80302 (W. Atlantic marine mollusks).
- Wolfenberger, Dr. Virginia A., 8200 Palm #119, New Orleans, LA. 70118 (Physiology).
- Work, Robert C., 7610 S.W. 63rd Court, South Miami, FL. 33143.
- Wright, Bill, 1473 Woodland, Abilene, TX. 79605 (*Cypraea*).
- Wright, Fran, 11422 SW 113th Place, Miami, FL. 33176.
- Wright, Kirk E. and Andrew, Box 2191, Fitchburgh, MA. 01420.
- Wu, Shi-Kuei and Ching-Chen, c/o Univ. of Colorado Museum, Boulder, CO. 80309 (Functional morphology of mollusks; muricid gastropods; land and freshwater mollusks of Rocky Mountain area).
- Wurtz, Dr. Charles B., 3220 Penn St., Philadelphia, PA. 19129 (Terrestrial pulmonata).
- Yancey, Thomas E., Dept. of Geology, Texas A&M University, College Station, TX. 77843 (Bivalves in general; late Paleozoic bivalves, schaphopods and gastropods).
- Yochelson, Dr. Ellis, E. 501, U.S. Museum of Natural History, Smithsonian, Washington, D.C. 20560.
- Yokley, Paul Jr., Ph.D., 3698 Chisholm Rd., Florence, AL. 35630.
- Young, Ann Frame, 11494 4th Ave., Ocean, Marathon, FL. 33052 (Scuba; Cassidae).
- Young, Carl T. Jr., 621 Chase, Corpus Christi, TX. 78412.
- Young, Donald J., 11975 Third St., East, Apt. 5, Treasure Island, FL. 33706 (Worldwide marine).
- Young, H.D. and Wilma G., P.O. Box 1931, Seattle, WA. 98111 (Exchange "documented" gastropods of Pacific Northwest for "documented" species from other areas; also purchase).
- Young, M.E. (Miss), P.O. Box 29, Falls Church, VA. 22046 ("The Shell Cabinet" owner).
- Zager, Mrs. Jane, 519-C Crooked Lake Lane, Fort Pierce, FL. 33450 (American shells).
- Zale, Alexander V., 118 Newins-Ziegler Hall, School of Forest Resources and Conservation, Univ. of Florida, Gainesville, FL. 32611 (Unionacean reproductive biology).

CORRESPONDING MEMBERS

- Ant. Professor Herbert, Dahlienstr. 38, 4700 Hamm, Germany.
- Baba, Dr. Kikutaro, Shigagaoka 35, Minami-11-jo, Sang-cho, Ikoma-gun, Nara-ken, Japan 636 (Opisthobranchia - taxonomy, morphology).
- Boletsy, Sigurd, Ph.D., Laboratoire Arago, F-66650 Banyuls-sur-Mer, France (*Cephalopod* biology and development).
- Bosch, Dr. Donald T., 9088 Mina Al Fahal, Muscat, Sultanata of Oman.
- Bylund, Gwen, P.O. Box 2, Manama, State of Bahrain, Arabian Gulf (Cones, cowries from the Indian Ocean—Mauritius).
- Cain, Dr. Arthur J., Dept. of Zoology, University of Liverpool, P.O. Box 147, Liverpool, England L69 3BX.
- Caplan, Dov, Guatemala 17/25, Kiryat Hayovel, Jerusalem 96704, Israel.
- Cataldo, Jacques, Hameau du Colombier, Villa #4, 26270 Loriol-Sur-Drome, France (Cowries).
- Franchini, Mr. Dario A., Via Cremona 37, I.46100 Mantova, Italy (Mediterranean mollusks (Muricacea, Epithonacea, general)).
- Fuziwara, Tugio, Kamihiranomae kobayasi City, Miyazaki Prefecture, Japan.
- Habe, Tadashige, Fac. of Marine Science, Tokai Univ. 1000, Orido Shimizu, 424, Japan.
- Kessner, Vince, P.O. Box 1340 Townsville 4810, Queensland, Australia.
- Lee, Jacques Kim, 2 Preston Road, West Wimbledon, SW 20 055 London, England (*Cypraea*, *Conus*, *Oliua*, *Voluta*, *Harpa*, rare shells).

Maxwell, Tom, Officers Mess, SOAF, Masirah, P.O. Box 897, Muscat, Sultanate of Oman (Masirah Island: Oman; Cypraea and general).
 Miyauti, Dr. Tetuo, Miyademy Fisheries Lab., Mitsu, Futami-cho, Watarai-gun, Mie-ken, 519-06 Japan.
 Murray, Talbot, Fisheries Research Div., P.O. Box 19062, Wellington, New Zealand.
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 Oyama, Dr. Katura, c/o Toba Aquarium, Toba 3-3-6, Toba City, Mie Prefecture, 517, Japan.

Paget, Dr. Oliver E. Naturhistorisches Museum, Burgring 7, A-104, Vienna, Austria.
 Roses, Migul Parcerisas, Seashells Collector, Pablo Alcover, 76.2º.2ª, Barcelona 17, Spain (Worldwide shells).
 Savelli, Prof. Riccardo Giannuzzi, via P. 31 N. 19, Palermo 90146, Italy (Mitridae-costel; Lariidae, Epitonidae, Mediterranean seashells-anatomy, systematics, ecology).
 Upatham, Edward Suchart, Ph.D., Biology Dept., Faculty of Science, Mahidol Univ., Rama 6 Road, Bangkok 4, Thailand.
 Wong, Mr. H.Y., Flat 1 D, Ewan Court, 54 Kennedy Road, Hong Kong (General).

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Museum, P.O. Box 21025, 1000 HC Amsterdam, S. Gravenhage 3,
Netherlands.
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NOTICES

The Forty-Eighth Annual Meeting of the American Malacological Union will be held July 19-23, 1982, at New Orleans, La., with headquarters at the Fountain Bay Club. A major symposium entitled "International Symposium on Molluscan Genetics" is planned by President Louise Russert Kraemer. Interested participants in this meeting are asked to contact Dr. Kraemer at the Department of Zoology, Univ. of Arkansas, Fayetteville, AK 72701.

The Forty-Ninth Annual Meeting of the American Malacological Union is scheduled for August 7-13, 1983, on the campus of the University of Washington, Seattle, Wash., with Dr. Alan J. Kohn president. Anyone interested in helping Dr. Kohn organize symposia topics should contact him at the Department of Zoology, Univ. of Washington, Seattle, WA. 98195.

How to Study and Collect Shells, latest edition of AMU's popular symposium on the stated subject, may be purchased for

\$2.50 each from Paul Jennewein, Corresponding Secretary, Box 394, Wrightsville Beach, N.C. 28480. A special discount of fifty percent is offered when six or more copies are purchased. Postage is additional for the discount orders. U.S. funds are requested for overseas orders, and postage for these orders is additional.

The INDEX TO THE BULLETINS OF THE AMERICAN MALACOLOGICAL UNION through 1974 may be purchased from Treasurer Myra L. Taylor, 7602 McCullough Ave., San Antonio, TX. 78216, for \$5.00 postpaid in the U.S. U.S. funds are requested for overseas orders, plus postage for such orders.

We have a few copies left of the reprint from *Malacologia* of the 1968 AMU symposium on rare and endangered mollusks. Order these from Recording Secretary Constance E. Boone, 3706 Rice Blvd., Houston, TX. 77005, for \$1.25 postpaid in U.S. postal zones. U.S. funds and postage required for overseas orders.

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Broward Shell Club Gene D. Everson
Palm Beach County Shell Club John Root
Greater Miami Shell Club David Pugh

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Fred Thompson	George Davis
Carol Stein	

WORKSHOPS

Salt water aquaria. John Root
How to collect and identify fossil shells. Edward Petuch
How to collect and identify freshwater shells. Fred Thompson

REVIEWERS FOR THIS ISSUE

Melbourne R. Carriker	William G. Lyons
Joseph Rosewater	William H. Gilbert
Dorothea S. Franzen	A. Myra Keen
George M. Davis	Kenneth M. Boss
Henry van der Schalie	Alan J. Kohn
Cliff Coney	Sam Rogers
Alan Solem	John Francis
Fred Thompson	

INFORMAL PRESENTATIONS

Bartram and Audubon Shells. Harry G. Lee
Snails in the Sky. Dorothy E. Beetle
Reeve and Rare Miters. Leonard Hill
Pectinidae of the Caribbean. Mike Cahill
Fossil Mollusks. Ellis Yochelson and Robert Linsley
Shell collecting in Oman. Donald and Eloise Bosch.
Some New Hybrids of *Liguus fasciatus*. Archie Jones
Molluscan Egg Cases. Bea Winner









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